NPS-68-85-008

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OPTOMA Program Interim Report:
The Airborne Ocean Thermal Structure Mapping Project
February, 1983 through February, 1985

by

Marie C. Colton
Christopher N.K. Mooers

August 1985

Prepared for:
Office of Naval Research
Environmental Sciences Directorate (Code 420)
Arlington, VA 22217

NAVAL POSTGRADUATE SCHOOL

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS68-85-008	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OPTOMA PROGRAM INTERIM REPORT: THE AIRBORNE OCEAN THERMAL STRUCTURE MAPPING PROJECT		5. TYPE OF REPORT & PERIOD COVERED Report for February, 1983 to February, 1985.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Marie C. Colton; Christopher N.K. Mooers		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School, Monterey, CA 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; N0001484WR24051
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research (Code 420), Arlington, VA 22217		12. REPORT DATE August, 1985
		13. NUMBER OF PAGES 98
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Portions of this report were presented at the Fall Annual Meeting, AGU, San Francisco, 4 December, 1984.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AXBT (Airborne Expendable Bathythermograph) Data
Analog to digital AXBT data conversion
California Current System
Dynamic Oceanography
Physical Oceanography

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

See reverse side.

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S/N 0102-LF-014-6601

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The Airborne Ocean Thermal Structure Mapping Project
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The **OPTOMA** Program is a joint program of

Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943.

Center for Earth and Planetary Physics
Harvard University
Cambridge, MA 02138.

ABSTRACT

The goals of the OPTOMA Program are to develop an Ocean Descriptive Predictive System for the study and forecasting of the evolution of ocean mesoscale features, and the California Current System. The attainment of these goals requires the establishment of a broad-base ocean observing and monitoring system that includes, e.g., hydrographic research cruises, moored arrays, and remotely sensed data. In particular, to forecast the evolution of the oceanic flow field, the observing system must include a means of obtaining real-time, synoptic maps for the initialization and verification of the dynamical model(s) used. Because of their convenience and rapidity, P3 flights to deploy AXBTs are a clear choice for frequent mappings of the study domains.

Since February, 1983 six OPTOMA missions have been flown off the California Coast. Of these, four flights have been in the OPTOMA Northern California domain and two flights have been in the Central California domain. A total of 325 AXBTs have been successfully deployed in these regions. Analyses of these data reinforce recent discoveries about the character of the California Current System: the current regime is highly variable in nature and it is comprised of cool anomalies, mesoscale eddies, 'squirts' and jets, current filaments and fronts.

The AXBT synoptic maps are of greatest utility to the OPTOMA Program when they can be used in near real-time. To fulfill this need, an Airborne Digital Data Acquisition System was fabricated at NPS. This system, which is built around an HP9816 microprocessor and a Sippican MK9 digitizing unit, digitizes the AXBT audio signal, then stores the profiles on diskette. The system was successfully tested on the OPTOMA13P and 15P flights and can now be considered to be completely operational.

With the digital data acquisition problem solved, the open issue is now how to exploit fully the aircraft missions. Steps being taken in this direction include expansion of the onboard software library to include 'first-look' data plotting and objective analysis routines, expansion to a suite of aircraft deployable airborne instruments which includes; e.g., expendable sound speed profilers and expendable CTD profilers (to be in production soon), and extension of the ADDAS to a multichannel, multi-instrument recording system.

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INTRODUCTION

OPTOMA Overview

The Ocean Prediction Through Observations, Modeling, and Analysis (OPTOMA) Program is a cooperative research effort between Harvard University and the Naval Postgraduate School, and is sponsored by the Office of Naval Research. The first phase of OPTOMA, initiated in March 1982, defined the two overall goals of the program: (1) to develop an Ocean Descriptive Predictive System (ODPS- a portable set of dynamical and statistical models, and an observational network designed for the study of oceanic mesoscale physics), and (2) to investigate the dynamics of the California Current System (CCS).

To attain these goals, an intensive field program was scheduled for the years 1982 through 1984. A total of fifteen quasi-synoptic studies have been accomplished to date in the OPTOMA Northern California (NOCAL) and Central California (CENCAL) study domains, Figure 1. There have been 16 research cruises and 4 research flights in the NOCAL domain, and 5 research cruises and 2 research flights in the CENCAL domain. The total number of XBT's, CTD's, and AXBT's deployed during Phase I surpasses 3000, and additions to the data base continue on approximately a bimonthly basis.

The prototype ocean prediction experiments, OPTOMA5 and OPTOMA11, were a series of four and six cruises (and one overflight) spanning five and eight weeks in the summers of 1983 and 1984, respectively. These series were planned so as to use the quasigeostrophic streamfunction evaluated from the dynamic height field acquired from the first cruise as an initialization field for the Harvard/NPS quasigeostrophic numerical model. The model then forecast the evolution of the input field. Subsequent cruises provided verification and re-

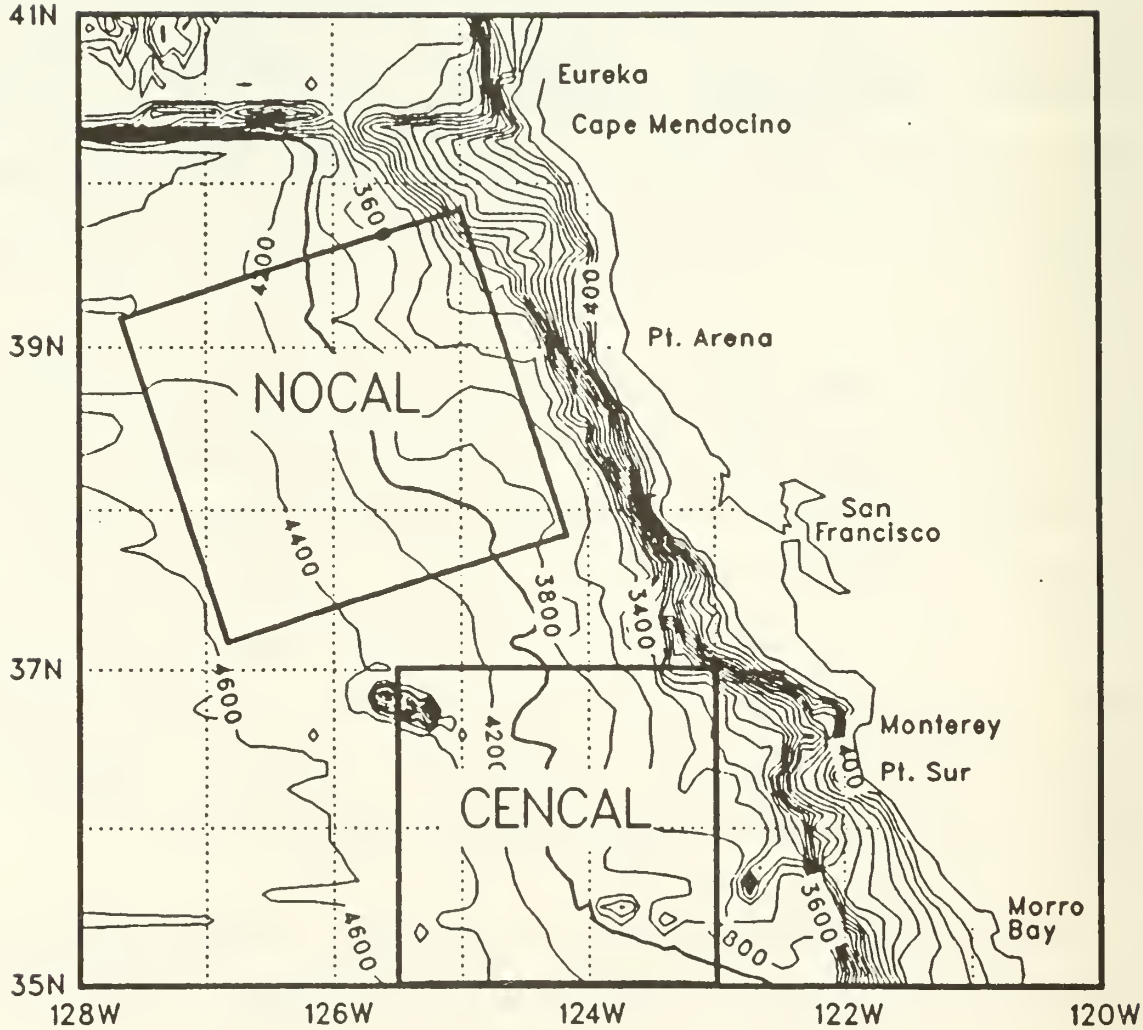


Figure 1: The NOCAL and CENCAL subdomains of the OPTOMA Program. Isobaths are shown in meters.

initialization fields. In these first real-time ocean forecasting experiments there was encouraging agreement between the forecast and verification fields (Robinson, et.al, 1984). From these numerical and statistical analyses of the hydrographic data, a new picture of the CCS emerged, which includes cool anomalies, mesoscale eddies, 'squirts' and jets, current filaments and fronts (Mooers and Robinson, 1984; Rienecker, et.al., 1985).

It is now recognized among the OPTOMA researchers that the initial stages of the project have evolved sufficiently to enter a second phase (OPTOMA Workshop Report, 1985). This phase will extend the two goals of the first phase and add a third. The three new goals are:

(1) the developmental ODPS tested in Phase I will be refined and implemented as a prototype system in the CCS,

(2) the ocean features revealed in the 'new picture' of the CCS will be examined analytically to determine the dynamical processes responsible for their formation, evolution, and destruction, and

(3) new applications of the ODPS to related areas of interest (e.g , biology, chemistry, acoustics, optics, marine meteorology) will be initiated.

Role of AXBT Surveys in the ODPS

Because of their convenience, speed, near all-weather capability, and the greater possibility for areal expansion of the study domain, P3 flights to deploy AXBTs are clearly desireable for the satisfaction of the first Phase 2 goal: an operational ODPS. Combined with moored and drifting buoys equipped with telemetering current meter and thermistor sensor/chains and with satellite remotely sensed data, monthly AXBT flights would complete an observing system which could provide the data base for the continually functioning ODPS. Other systems; e.g., acoustic tomography, inverted echo sounders and bottom pressure gauges, SOFAR and RAFOS floats could play significant roles, too, or even serve as alternatives. The oceanographic cruises would be focused on special physics and feature studies, as opposed to quasi-synoptic mapping of the domain. They would also be efficiently integrated with those cruises required for the installation, maintenance, and retrieval of instrumentation.

Scope and Purpose of this Report

The AXBT flights to date have been used (1) to examine the effectiveness of the AXBT as a data acquisition device within OPTOMA (OPTOMA3P), (2) to obtain a large-scale mapping of the CCS from Pt. Sur to Pt. Arena (OPTOMA8P), (3) to obtain the AXBT data in a digital form (OPTOMA11P) using the digital data acquisition system developed at Scripps Institute of Oceanography, (4) to evaluate the degree of synopticity of shipboard hydrographic data (OPTOMA13P, OPTOMA15P), and (5) to develop and test an Airborne Digital Data Acquisition System (ADDAS) for the real-time digitizing and processing of the AXBT audio signal (OPTOMA13P, OPTOMA15P). The purpose of Part One of this report is to trace the development and implementation of the airborne ocean thermal structure mapping project through elaboration of the first four points above. In Part Two, the design and operation of the ADDAS is described.

PART ONE: THE OPTOMA FLIGHTS

I. FLIGHT PLANNING AND OPERATIONAL PRODUCTS

Flight Coordination

In response to a formal request to CNO (Chief of Naval Operations) initiated in October, 1982, a CNO Project number for P3 services of Navy active duty or reserve squadrons on a not-to-interfere basis was authorized for the OPTOMA Project. The flights were scheduled through the Operations Officers of the particular squadron assigned each flight. Subsequent liaison activities, such as confirmation of the flight plan, details of the mission schedule, and transportation of the AXBTs and equipment, were conducted either through the Tactical Coordinator of the assigned crew from the operational squadron, or the Training Officer of the reserve squadron. Permission was granted for civilian observers to participate on OPTOMA11P and OPTOMA15P after completion of a survival swim test, a low pressure/night vision certification test, an emergency procedures training course, and a security clearance investigation.

Planning Factors

All OPTOMA flight plans are flexible. The willingness and capability to accept changes in the flight schedule (date or duration) and track is essential because of the numerous factors which may alter the schedule of a military aircraft. Given the date and duration of the flight, the planning of the track is straightforward and follows the logic of a standard oceanographic cruise plan. The relevant points to consider are: (1) the cruising speeds and altitudes of the aircraft en route and on station, (2) the number of AXBTS to be deployed, (3) the minimum desired station spacing between deployments, (4) the depth ratings and associated transmission times of the AXBTs, (5) the number and frequencies of the AXBT transmission channels, and (6) whether or not a multichannel recording system is available.

The cruising speed and aircraft endurance determine the distance which may be covered in a single flight, usually about 1600 nm in eight hours. A typical value for the speed en route is 300 knots (air speed); while on station the speed can vary between 160 to 210 knots. A slower speed (ca. 160 knots), or a temporary holding pattern, may be necessary when a single channel recording system or deep AXBTs are used, so as to minimize the distance covered between deployments. Aircraft altitude is important because of the direct effect of increased drag with lower altitude on fuel consumption; it also affects the tolerable minimum distance between buoy deployments due to line-of-sight interference on the same channel. In general, the altitude maintained during an AXBT mission is lower than optimal for a P3 aircraft; therefore, the maximum duration of the flight may be fuel-limited and shorter than a nominal mission of eight to ten hours. It is best to request a maximum capacity fuel load to allow for increased fuel consumption due to lower altitude, and to allow for additional flight time for replacement of the AXBT failures that invariably occur.

Items (1) through (6) are interrelated. The shallow (305m) and deep (760m) AXBTs transmit for 200 sec and 500 sec, respectively. Set-up of the data acquisition system, launching of the buoy, annotation of the log sheets and analog traces, and storage of the data takes approximately five (nine) minutes per shallow (deep) AXBT. Time is a most important factor when only a single channel recording system is being used. If a multichannel system is available (e.g, a commercial multichannel audio tape recorder or the onboard 14 channel audio magnetic tape recorder-reproducer system), then alternate channel

AXBTs can be launched closer together and the overlapping radio signals recorded simultaneously. At present, standard production AXBTs transmit on one of three channels: 12, 14, and 16; the frequencies of these channels are 170.5, 172.0, 173.5 MHz, respectively. Channels 14 and 16 can be used off the northern California coast; channel 12 should not be used as it is the emergency broadcast channel of the California Forest Service.

The number of AXBTs which can be deployed is limited by the capacity of the aircraft (approximately 78) and the flight duration. The number of successful AXBT profiles is limited by the failure rate of the AXBTs (usually 5 to 15%, manufacturer and lot dependent) and occasional operator errors. No radio frequency transmission, or a weak and wavering transmission, are the most common reasons for an AXBT failure. In rough sea conditions an AXBT may be lost, or short data dropouts may be encountered, due to washover by an ocean wave.

Operational Products

After each flight, the AXBT profiles are edited: failures not identified during the flight are deleted from the data set; blunder points are deleted from the profiles; bottom 'tails' on the profiles are truncated; times, dates, and positions are corrected; and to smooth the profiles a three-point Tukey (median) filter is applied .

A. Objective Analyses

After completion of the data editing process, the AXBT data are interpolated to a grid using an inverse distance weighting to compute a grid point value from the four closest observed values, within a 100 km radius. The gridded values are then contoured using a bilinear interpolation routine.

The variables most commonly displayed in this manner are temperatures at a specified depth, depths of a specified isotherm, and dynamic height relative to a specified reference level.

Proxy salinity profiles are estimated from the AXBTs and the T vs S relations determined from the CTD data acquired during the quasi-synoptic cruises. They are used together with the temperature profiles to calculate dynamic heights relative to 300m.

Geostrophic velocity and baroclinic mass transport are also computed and then mapped by an objective analysis (OA) routine which uses an exponential decay correlation function, with a zero crossing of approximately 50 km, for the computation of the grid point values from the observed values.

B. Reports

Prior to each mission, a flight plan, which includes a proposed flight track, is provided to the squadron liaison officer for review and approval. A flight report and a data report are produced after each flight. The flight report describes the itinerary and specifics of each flight, critiques the operations, and provides preliminary analyses of the data acquired. The data report, produced after final editing of the data, describes the data processing sequence and provides maps of station positions and numbers, figures of the edited AXBT profiles, isotherm transects, and a mean temperature profile. Data from the OPTOMA3 and OPTOMA8 flights were issued as separate reports (Colton, et.al., 1985; Wittmann, et.al., 1985); data from OPTOMA11P, 13P and 15P were included in the OPTOMA11, 13, and 15 hydrographic data reports (Wittmann, et.al., 1985). The data and data reports from all of the flights discussed in this report have been archived with NODC.

II. OPERATIONAL AND SCIENTIFIC RESULTS FROM THE OPTOMA FLIGHTS

A. OPTOMA3

This mission was authorized by Commander, Patrol Wing Pacific, Wing 1((COMPATWNGTEN), and flown on 10 Feb 83 by an active duty squadror stationed at Moffett Field, CA. A one-time flight waiver was issued for ar NPS student, a naval officer, to participate as a flight observer for the purposes of liaison with the flight crew and documentation of a typical AXBT mission for use in planning future flights.

Seventy-two AXBT stations were planned at a spacing of 28 km; the actual flight track and station positions are shown in Figure 2. A shallow (305m) or deep (760m) Sippican AXBT was deployed at each station. The aircraft maintained an altitude of approximately 1500 ft and an airspeed of 210 knots during the drops. To minimize spatial separation, the average time between stations was 4.5 minutes, which resulted in truncation of some of the deep AXBTs which transmit for 7 minutes or more. The AXBT profiles were recorded on audio tapes, using the onboard 14-channel audio recorder, and as analog traces using two lofargram recorders. These recorders were operated on the AXBT VHF channels 14 and 16. Station positions were obtained from the aircraft's Inertial Navigation System (LITON-72 INS) with hourly updates by radar and Tactical Air Navigation (TACAN). For a description of the navigation systems used, and for estimates of the position accuracy from each, see Appendix A.

The analog traces were visually digitized using a gridded template overlay which is manufactured to represent the Navy frequency-to-temperature and fall-rate to depth equations. This procedure yields approximately 25 to 30 points per profile with accuracies in temperature and depth of ±0.40C and ±6.25m, respectively. These data were then transferred to the IBM 3033 mainframe computer at NPS and edited by removing obvious AXBT failures that were not identified during the flight or digitization procedure. Of the 70 AXBTs deployed, eight instrument failures and one suspected instrument failure were edited from the final data set, yielding a retention percentage of about 87%.

The warmest temperatures (15C) in the OPTOMA3 sea surface temperature (SST) field, Figure 3, were in the southwestern quadrant of the domain, and the coolest temperatures (less than 13C) were observed in the northwestern quadrant of the domain. There was also a meandering temperature front of 0.8C range, oriented northeast-southwest through the center of the domain. The front exits from the western side of the domain but this result should be viewed with caution as this is an area which lacks observations (Fig. 3; c.f., Fig. B-1). In the corresponding surface dynamic height map, Figure 4, there was a cyclone of at least 3 dyn-cm range and ca. 100 km diameter in the northwestern quadrant. There was a meandering onshore current, parallel to the temperature front and there was evidence of southward flow in the southeastern quadrant of the domain and an anticyclonic feature in the northeastern quadrant. The overall dynamic height range observed in this mapping was 17 dyn-cm.

B. OPTOMA8

After OPTOMA3, COMPATWNGTEN at Moffett Field received cutbacks in funded flight hours and fuel allotments; therefore, dedicated eight-hour OPTOMA flights could not be scheduled. Instead, attempts were made to drop

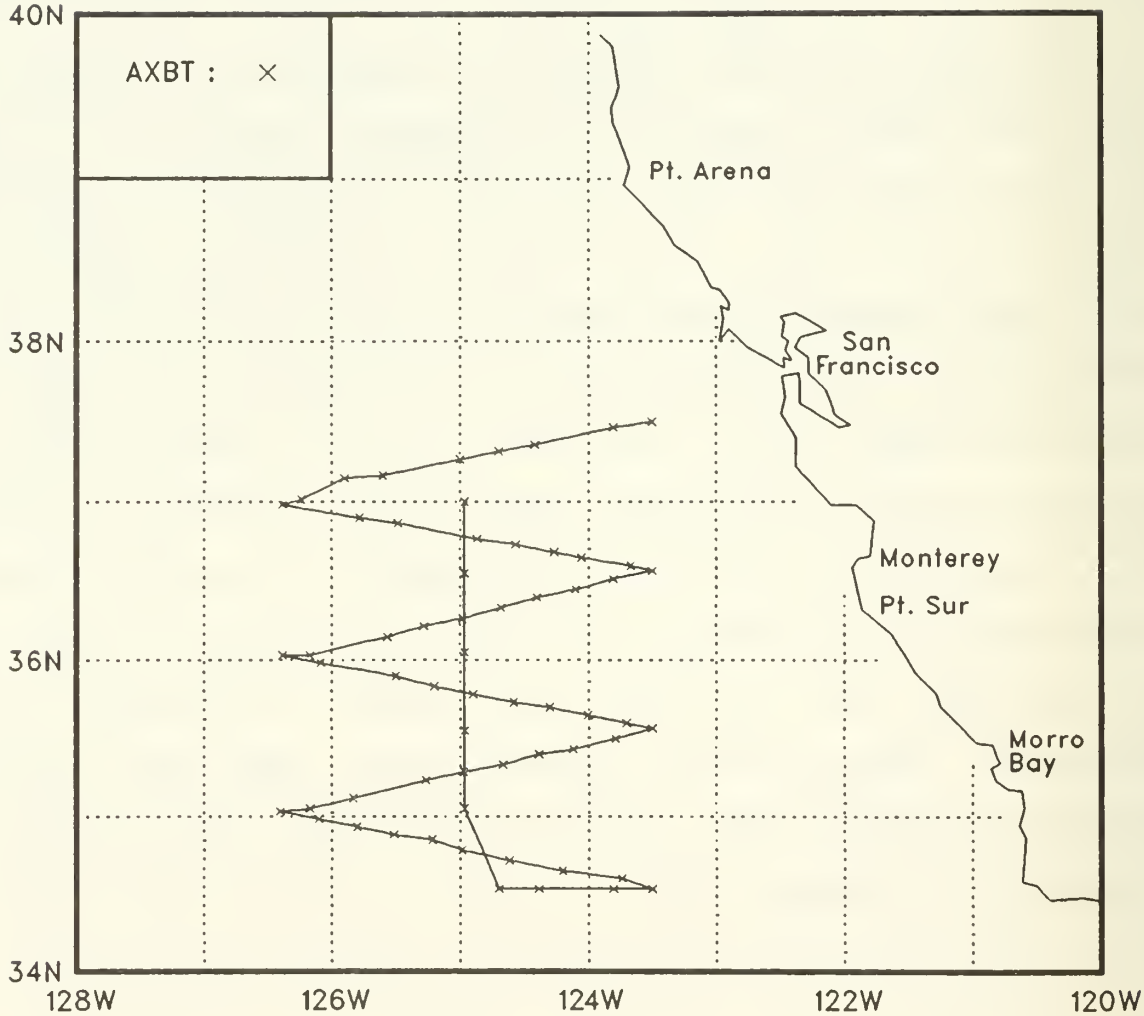


Figure 2: Flight track and station positions for OPTOMA3.

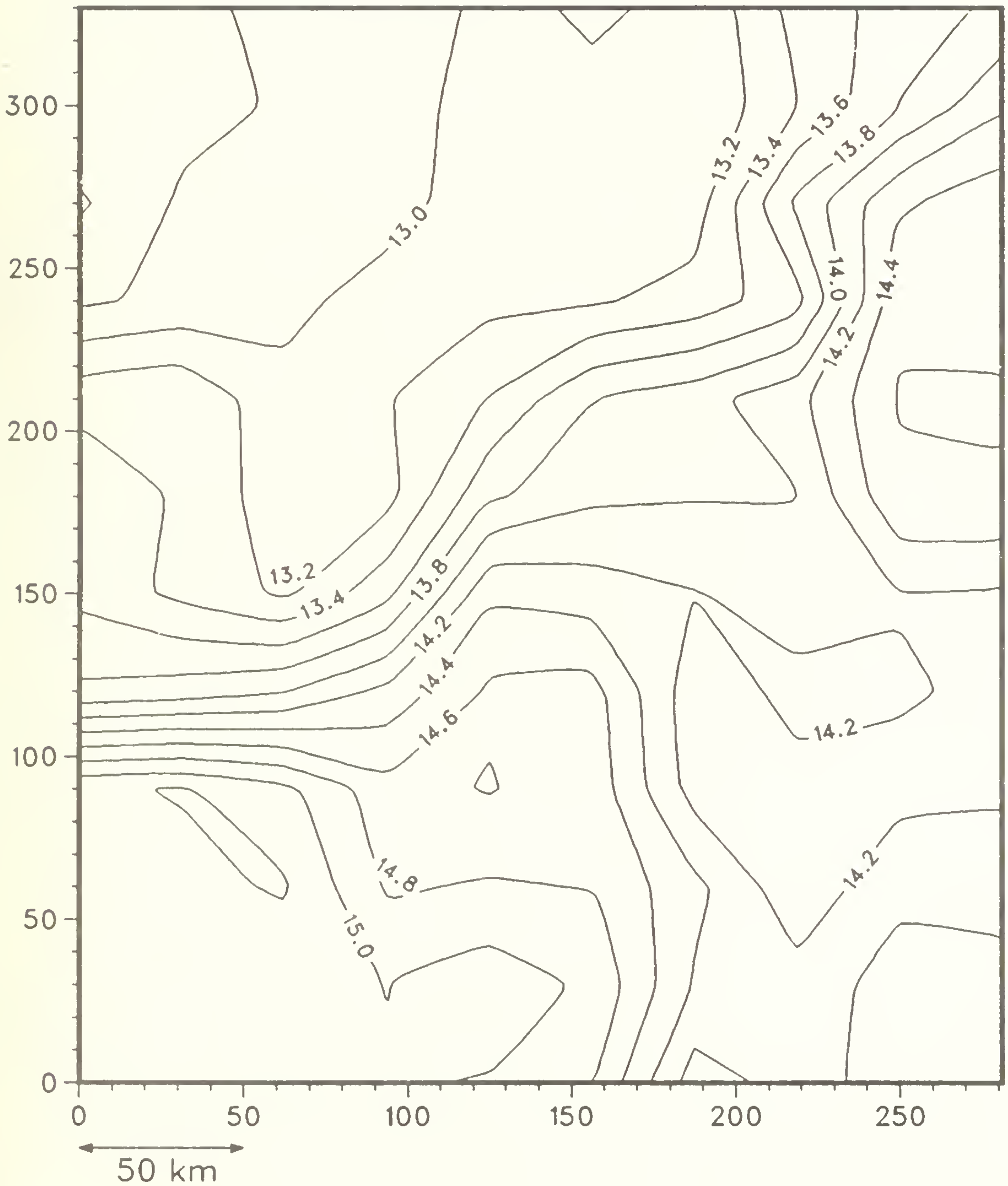


Figure 3: Objective analysis of sea surface temperature (OPTOMA3).

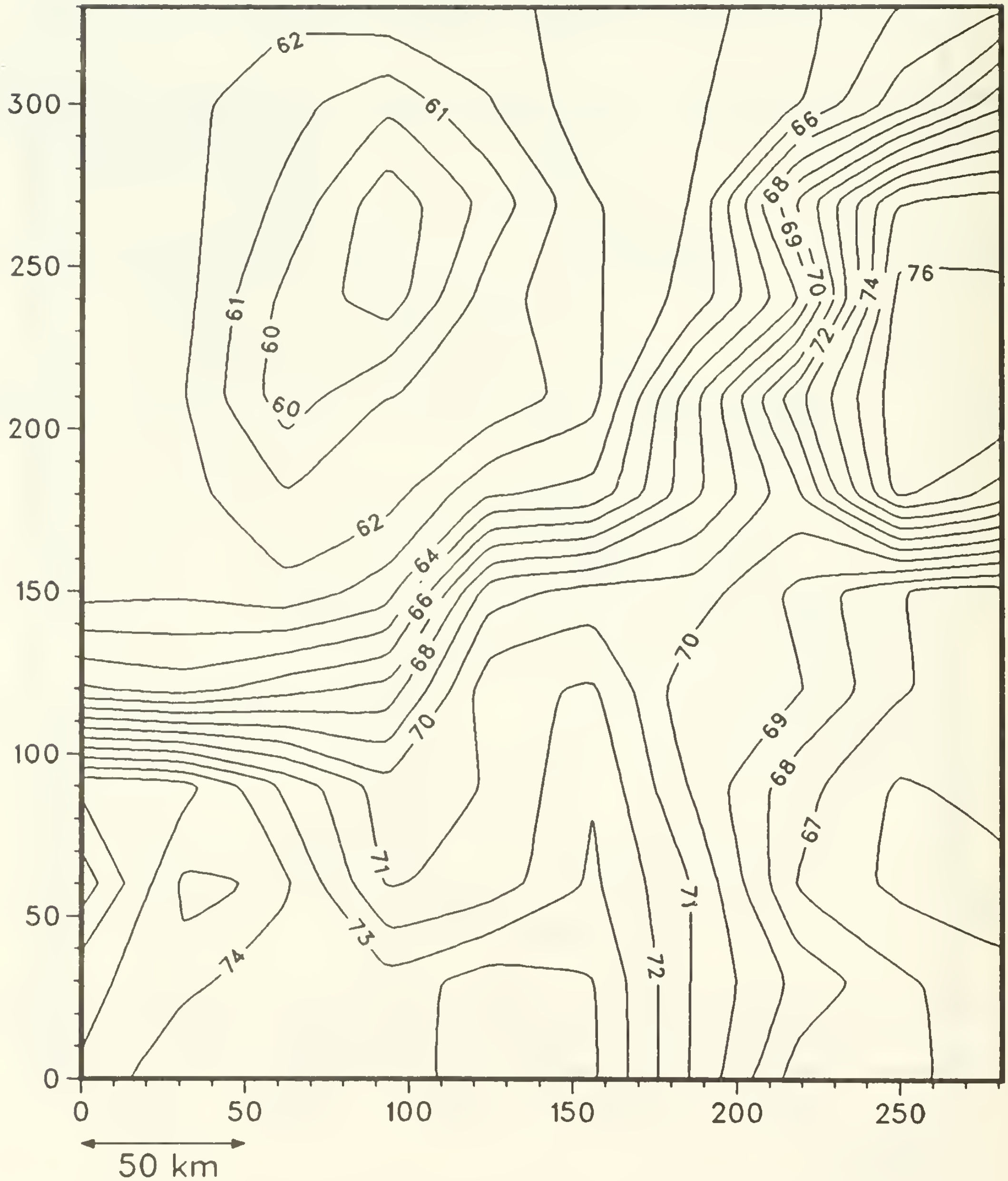


Figure 4: Objective analysis of surface dynamic height relative to 300m (OPTOMA3).

a limited number of AXBTs whenever possible near the OPTOMA domains during the course of operational missions. Usually, only ten or so AXBTs could be deployed on a flight and the positions of the drops could not be predetermined or guaranteed to be within the study domains. Between February and December 1983, a total of 72 AXBTs were deployed: 20 each on three consecutive days in April, south and west of the CENCAL domain, and 12 on 20 July, north of the NOCAL domain over the Mendocino Escarpment (Figure 1).

It became clear that alternative P3 sources would have to be sought and in November a request was placed through the Commander, Antisubmarine Warfare Wing, Pacific (COMASWWINGPAC) San Diego, regarding the possibility of flying with a reserve patrol wing. The request coincided in time with the planning of certain reserve wing exercises scheduled for December at Moffett Field. Thus, two flights were scheduled within five days of each other, enabling a large-scale wintertime mapping of the CCS to be obtained.

The flight tracks and the stations were executed as shown in Figure 5. The flight on 10 December, Leg I, covered the northern half of the domains; the flight on 15 December, Leg II, covered the southern half of the domains. Data from the two flights were combined and treated as a single synoptic data set, bounded by Pt. Sur in the south and Pt. Arena in the north. This combination yielded a large areal mapping extending roughly 420 km alongshore by 350 km crosshore. Station spacing was about 40 km alongtrack. During Leg I shallow and deep AXBTs were deployed; during Leg II only shallow AXBTs were deployed. The aircraft maintained an altitude of approximately 1500 ft and an airspeed of 230 knots. The data were recorded onboard on audio tapes using the 14-channel recorder and as analog traces on two

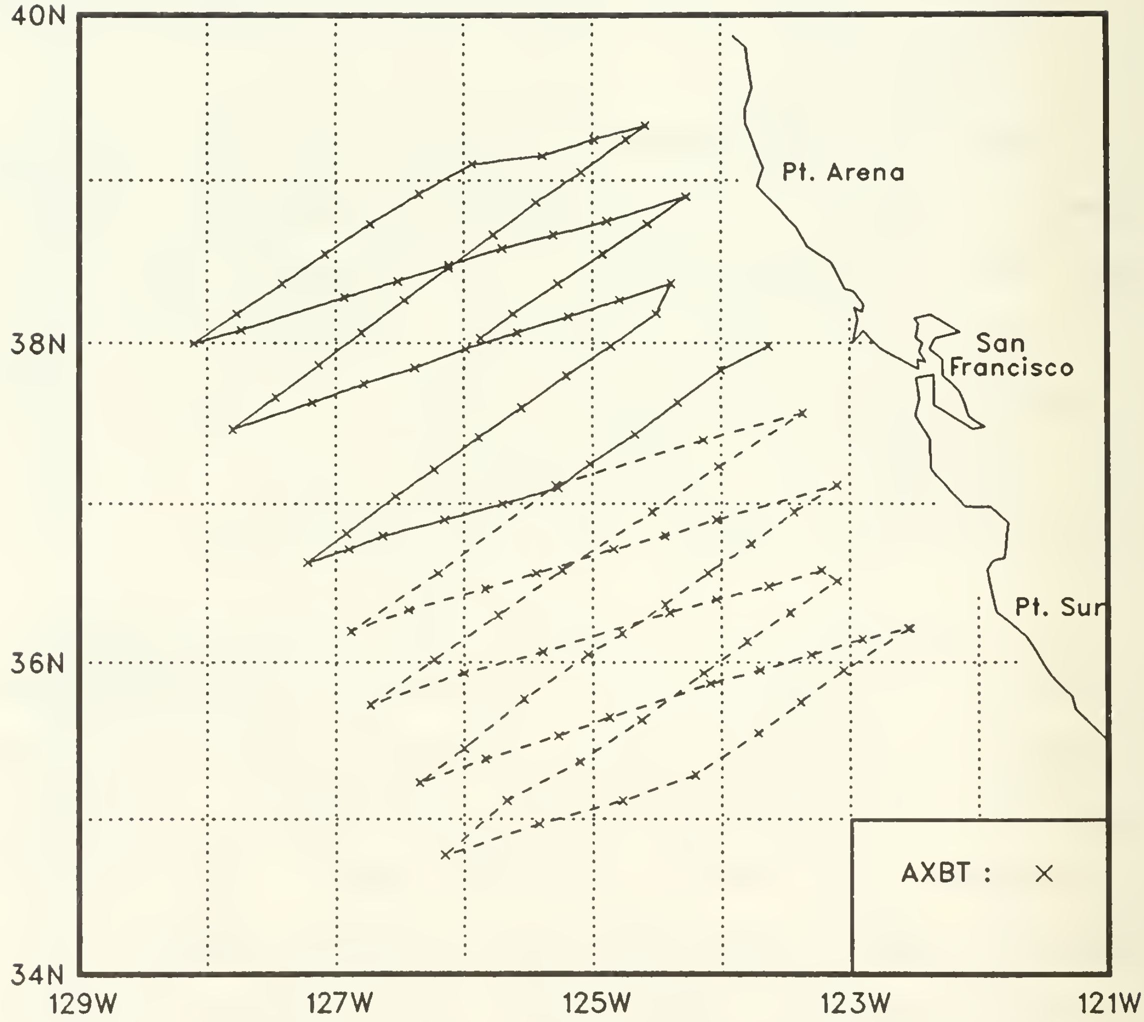


Figure 5: Flight track and station positions for OPTOMA8.

lofargram recorders, which monitored the AXBTs on UHF channels 14 and 16. Station positions were obtained from the aircraft's INS with hourly updates by radar and TACAN.

The data were digitized, using a Hewlett-Packard digitizing pad, by Naval Oceanographic Office (NAVOCEANO) personnel in Bay St. Louis, MS. Only inflection points were digitized, giving an average of about 15 points per shallow profile and about 20 points per deep profile. The data were provided for OPTOMA on magnetic tape about three weeks after the flight and were transferred to the IBM 3033 for editing. From the Leg I data set, approximately 97%; i.e., 37 deep and 23 shallow casts were recovered. From the Leg II data set, approximately 90%; i.e., 55 shallow casts were recovered.

From the SST map, Figure 6, a cool anomaly (less than 14C) extended offshore in the central eastern portion of the domain. There was a southward temperature gradient of +1C in 100 km in the southern 100 km of the region, and a slightly warm intrusion in the northwest quadrant. In the surface dynamic height map, Figure 7, a cyclonic feature was present in the region of coolest SST. A southward jet flowed along the perimeter of the cyclone. An eastward jet along the southern edge of the domain was associated with the southward temperature gradient. North of this jet, in the western half of the domain, was a large, irregularly shaped anticyclone in the region of the warm intrusion. The overall dynamic height range in this map was 20 dyn-cm.

C. OPTOMA11P

Manual digitization of the OPTOMA3 and OPTOMA8 analog traces was labor intensive and produced profiles of low resolution. In addition, completion of the procedure required several weeks, effectively negating the real-time

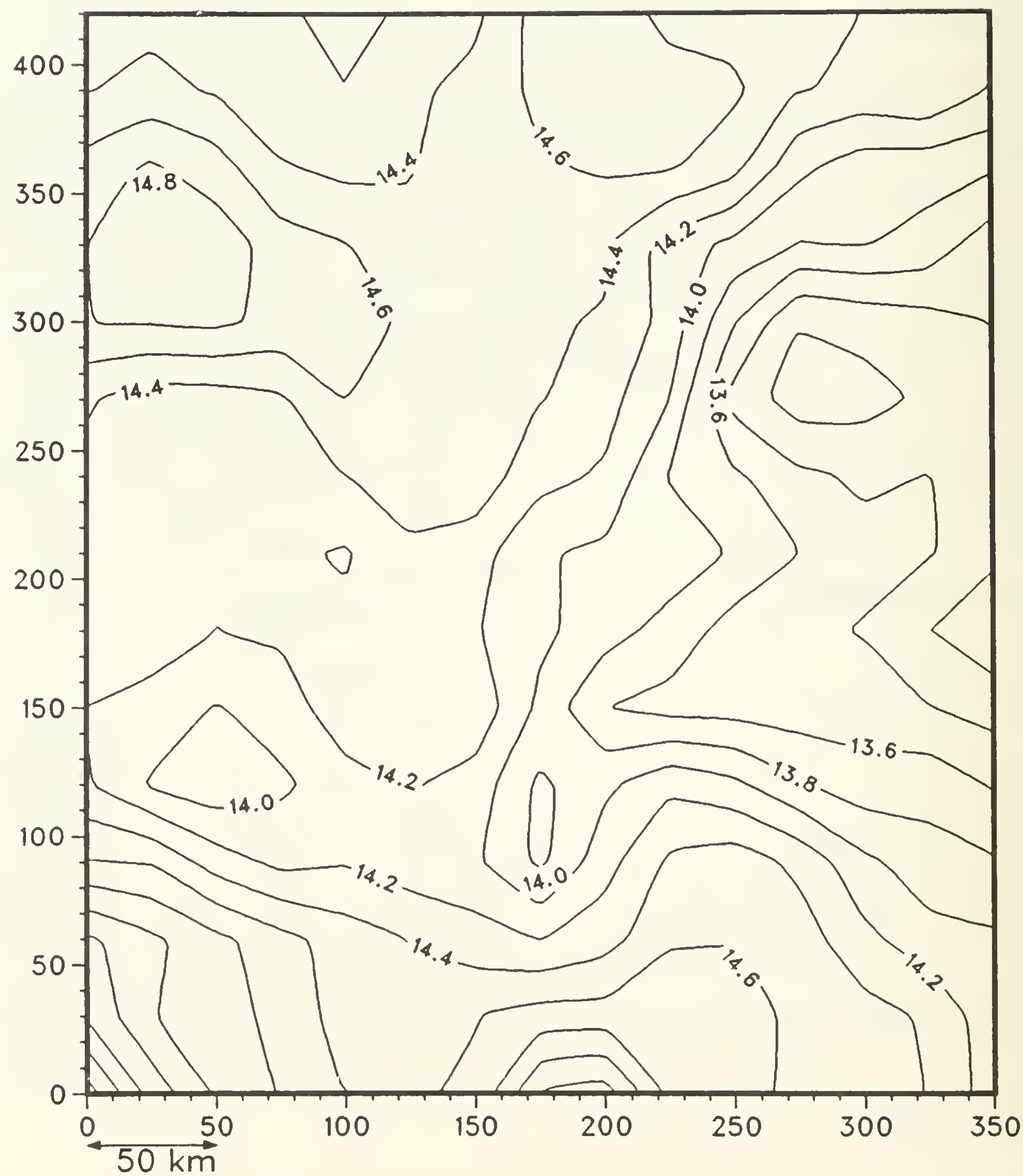


Figure 6: Objective analysis of sea surface temperature (OPTOMA8).

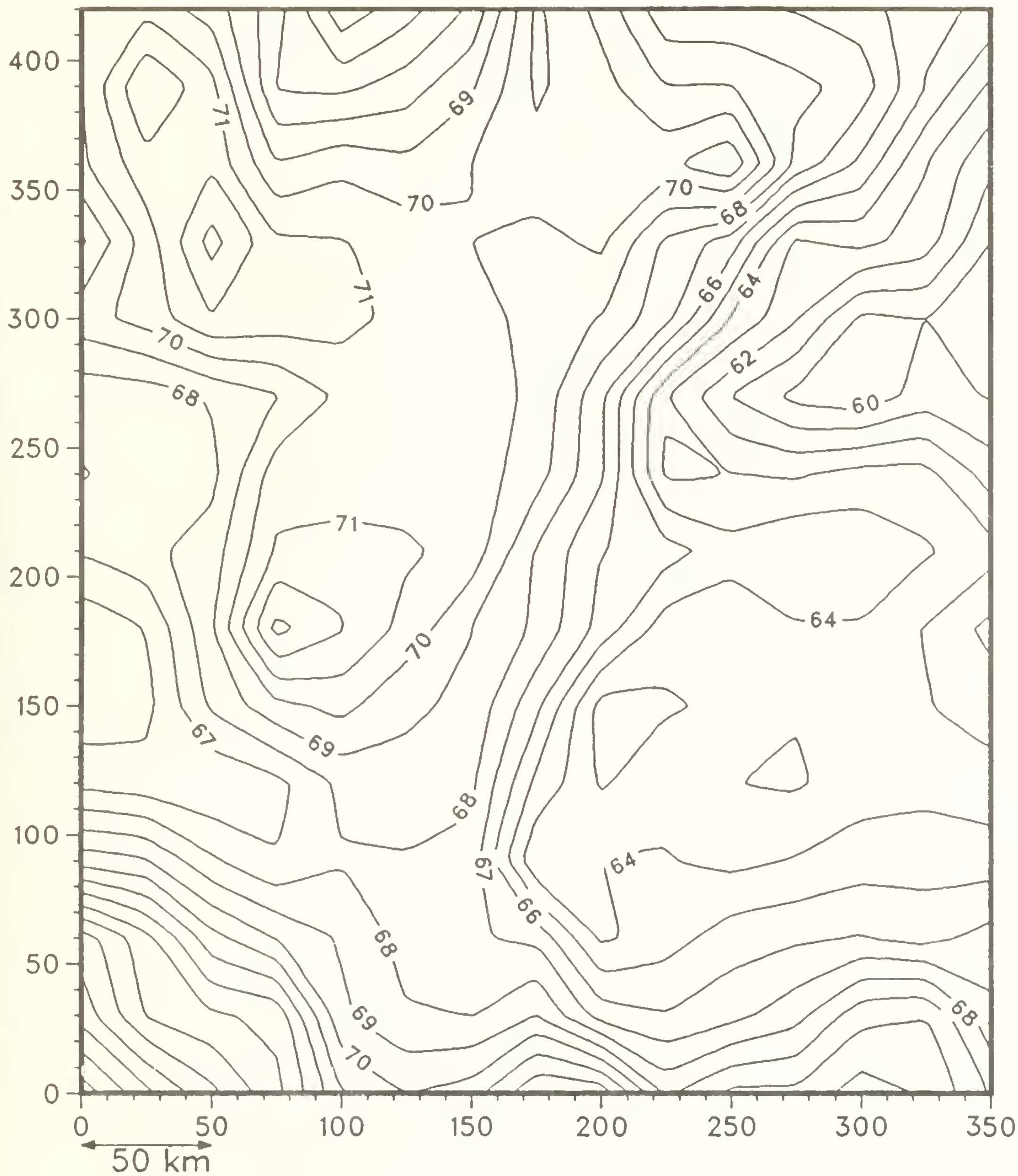


Figure 7: Objective analysis of sea surface dynamic height relative to 300m (OPTOMA8).

mapping capability of the AXBT missions. For the flights to be of greates utility to OPTOMA, it became necessary to find a means of acquiring the dat digitally in real-time.

It was learned that the analog-to-digital signal conversion system develope by M. H. Sessions at the Scripps Institution of Oceanography and used in th NORPAX (North Pacific Experiment) (Sessions, 1980) could be made availabl for use on the OPTOMA flights. This system uses a redundant pair o frequency counters to convert the incoming audio signal to a digital frequency First-order smoothing of the profile is accomplished by averaging the frequenc counts over a one second interval, yielding approximately 200 points per profil with depth and temperature resolution capability of 1.5m and 0.03C (±1 Hz) respectively (with the Gent equation, to be explained in the OPTOMA13 discussion). This averaging technique does not impair the quoted instrumen accuracies of ±0.18C in temperature and 2% in depth. Each point is the stored on a digital cassette tape. The digital cassette is copied postflight t a magnetic tape and the data are then transferred to a mainframe computer.

For monitoring the AXBT profile, the system also produces an analog trac and a hard-copy printout of the frequencies in real-time. Time and position ar displayed in LED readouts. As a backup measure, a stereo tape recorde independently duplicates the incoming audio signal during the flight fo postflight playback through the digitizing portion of the system in th laboratory.

Since the digitizing system was in use elsewhere on the date of th OPTOMA11P flight, Mr. Sessions volunteered to participate as the fligh observer and record the AXBT profiles on a stereo tape recorder for post processing in his laboratory at Scripps. The processing was performed withi

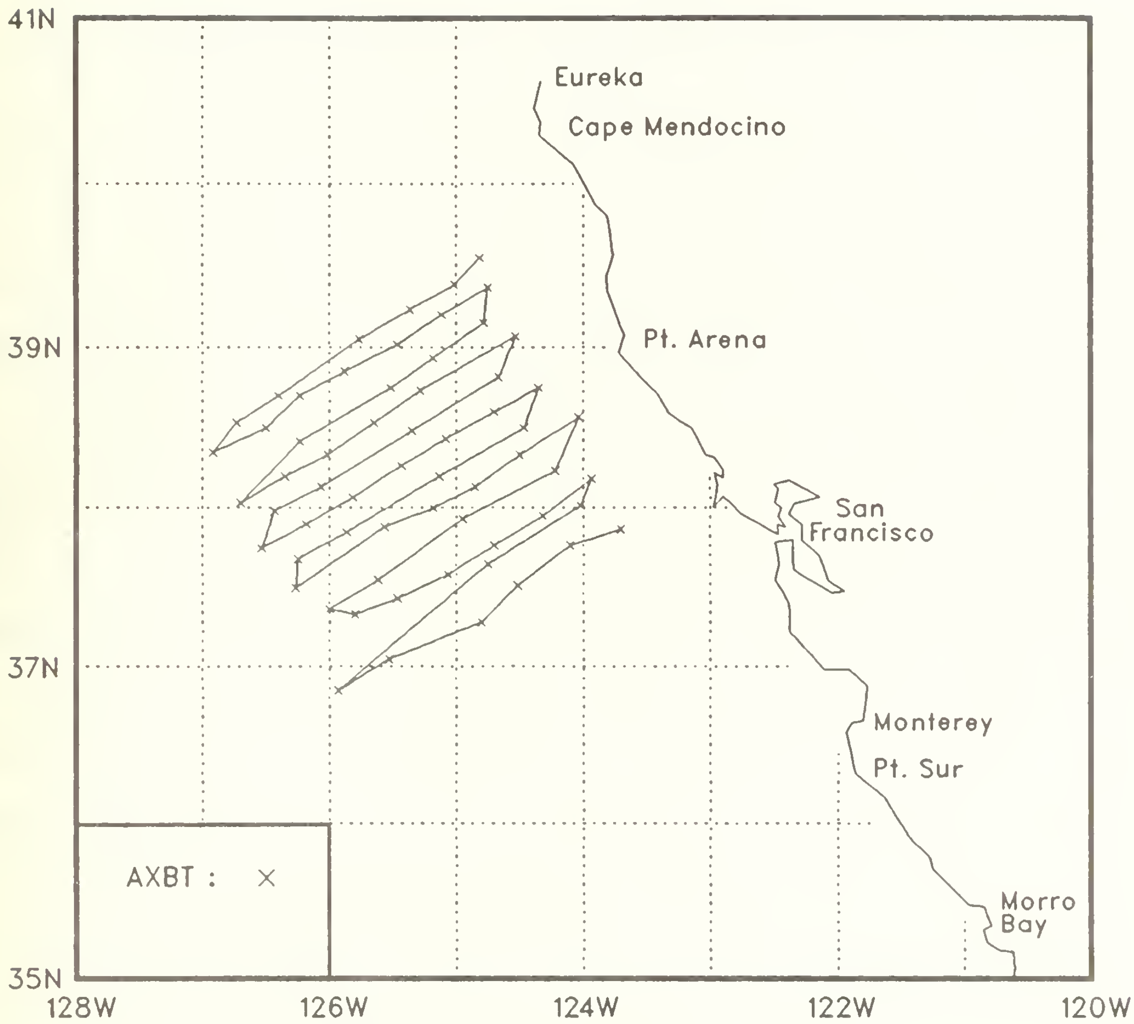


Figure 8: Flight track and station positions for OPTOMA11P.

ten days and the data transferred to the IBM 3033 at NPS for editing.

Sixty-eight AXBT stations were planned for OPTOMA11P at a spacing of 36 km or 52 km; the actual stations were executed as shown in Figure 8. An approximate 250 km square was sampled in the NOCAL domain with an along-track spacing of about 36 km. The aircraft maintained an altitude of approximately 1500 ft and an airspeed of about 210 knots. Sixty-six shallow AXBTs were deployed; there were six failures in the field and three profiles deleted postflight for a retention percentage of approximately 87%. Navigational difficulties arose on this flight as a result of simultaneous failures of the INS and LORAN-C. Thus, the navigator had to determine positions manually from radio fixes received from shorebased stations. Accuracy of position is approximated to be ± 4 km at the inshore stations degrading to ± 8 km at the offshore stations.

From the SST map, Figure 9, there were (1) a southwestward oriented temperature front which exhibited rather sharp bends in direction, (2) a cool feature shoreward of the front and centered on Pt Arena, (3) a second temperature minimum in the southwest quadrant, and (4) a broad area of fairly constant warm temperature in the northwest quadrant. From the surface dynamic height map, Figure 10, there was a predominantly westward jet which deflected sharply to the south in association with an anticyclone in the northwestern quadrant. The southern half of the domain was dominated by a large cyclonic feature which contained at least two relative minima. There was a small anticyclonic feature just inside the southwestern edge of the domain. The overall dynamic height range in this map was 23 dyn-cm.

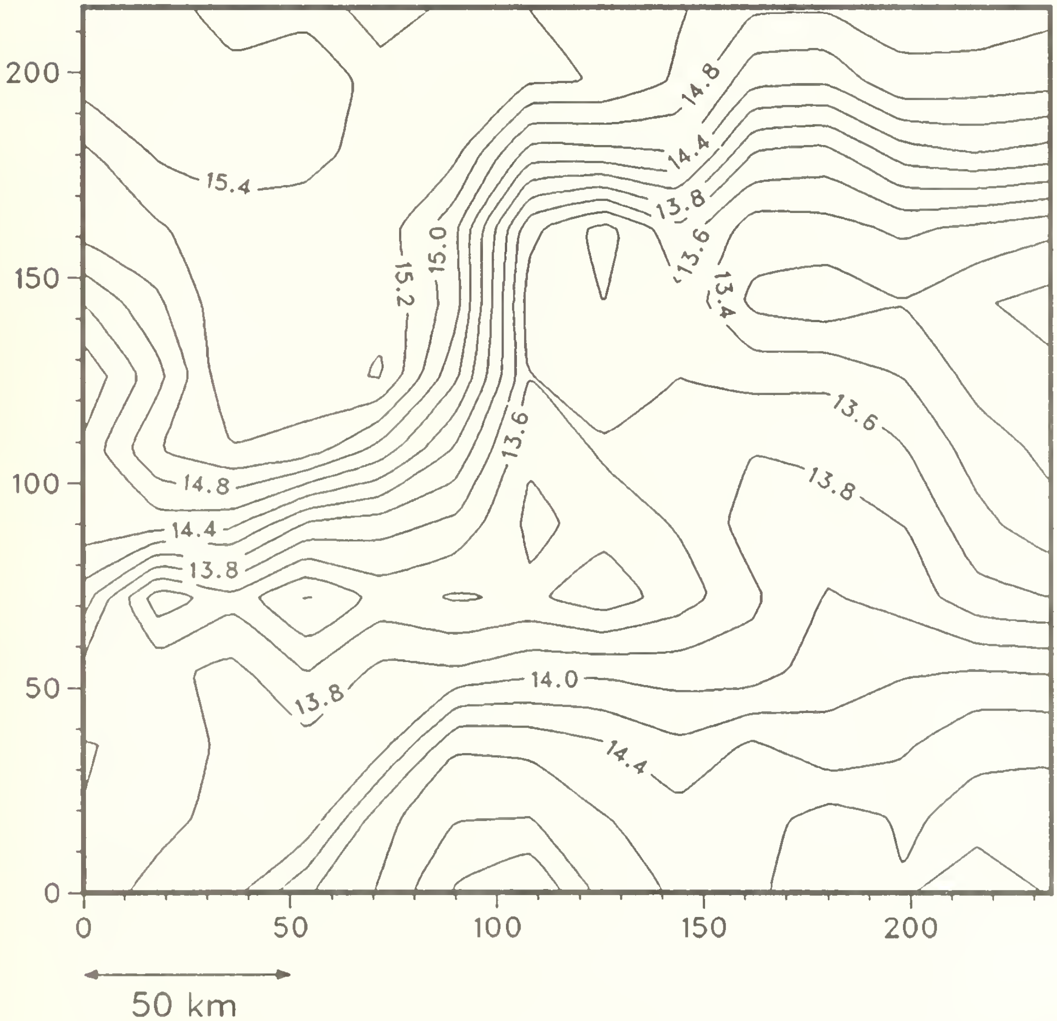


Figure 9: Objective analysis of sea surface temperature (OPTOMA11P).

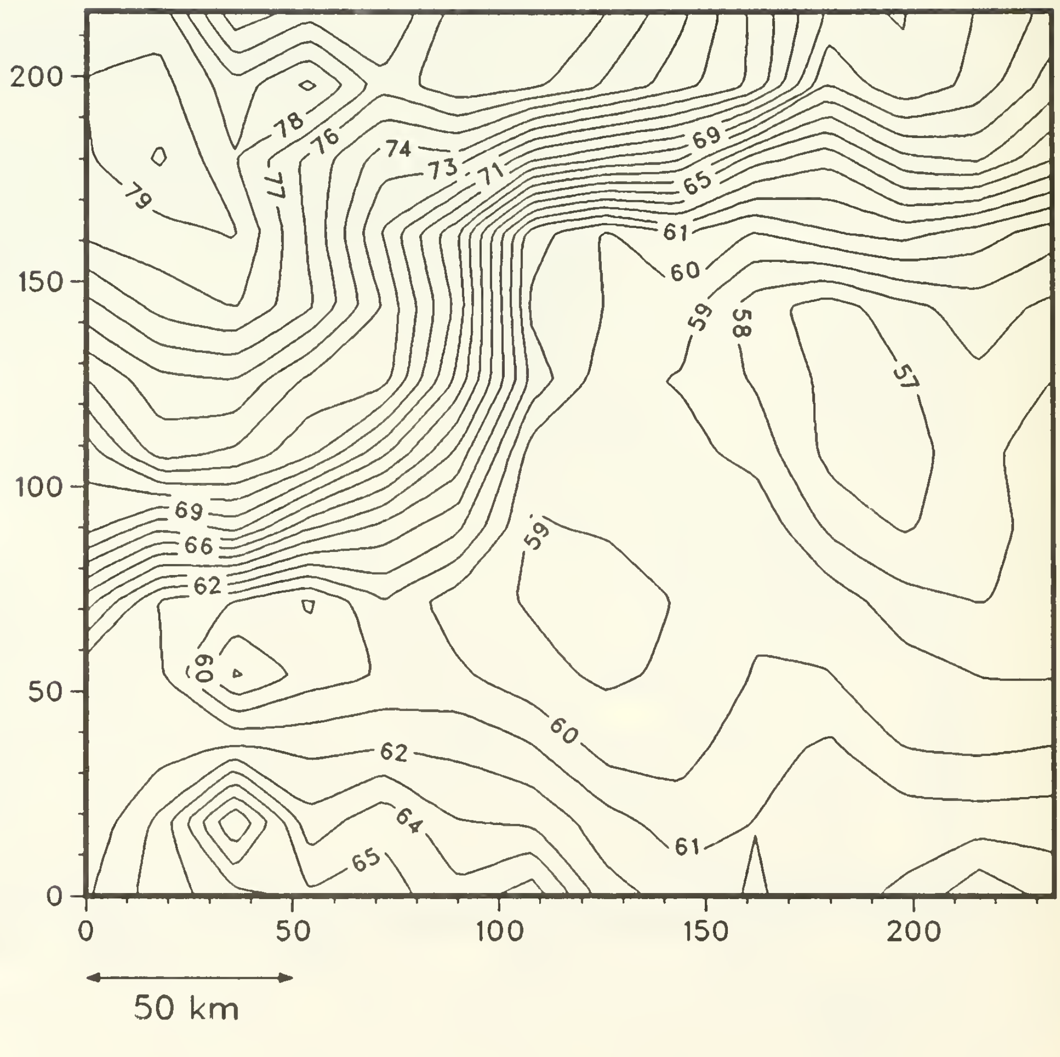


Figure 10: Objective analysis of surface dynamic height relative to 300m (OPTOMA11P).

D. OPTOMA13P (27 Oct 84)

Significant advances in the OPTOMA AXBT program were made during the course of planning and executing flights OPTOMA 3, 8 and 11P. In particular, comparison of Figure 11(a) with 11(b) shows the typical improvement in profile resolution gained from the use of the SIO data digitization (OPTOMA11P) vice hand digitization of the profiles (OPTOMA3) (for a complete comparison, a profile acquired by the Airborne Digital Data Acquisition System (ADDAS) is also shown in Figure 11(c)).

With only 35 points, the hand digitized profile, Fig. 11(a), is smooth. In general, subjectivity was more influential in determining the final representation of the hand-digitized profile; i.e., the small inversion at 400 m and the spike at the base of the mixed layer present in the analog trace were concluded to be erroneous points, rather than real structures, and ignored. Adding an average of 175 points to each profile, using the SIO digitization system, yielded a more realistic and objective representation of the analog profile (Fig. 11(b)). For example, the 'kink' in the mixed-layer at 25 m and the inversion at 160 m both were preserved. Smaller-scale variability along the length of the analog profile was maintained in the SIO digitized profile. The reason for the small inversion at 275 m which was not observed in the analog profile is not clear, although it could have been due to a slightly loose cable connection at the sonobuoy interconnection box which affected some of the OPTOMA11P profiles.

The convenience of data acquisition and improved resolution available from the SIO system suggested seeking permission for continued use of the system in the OPTOMA13 flight. However, the timely development of an AXBT digitizing circuit board for the Sippican MK9 XBT digitizing unit offered a second option. Since the OPTOMA shipboard DAS had been recently upgraded

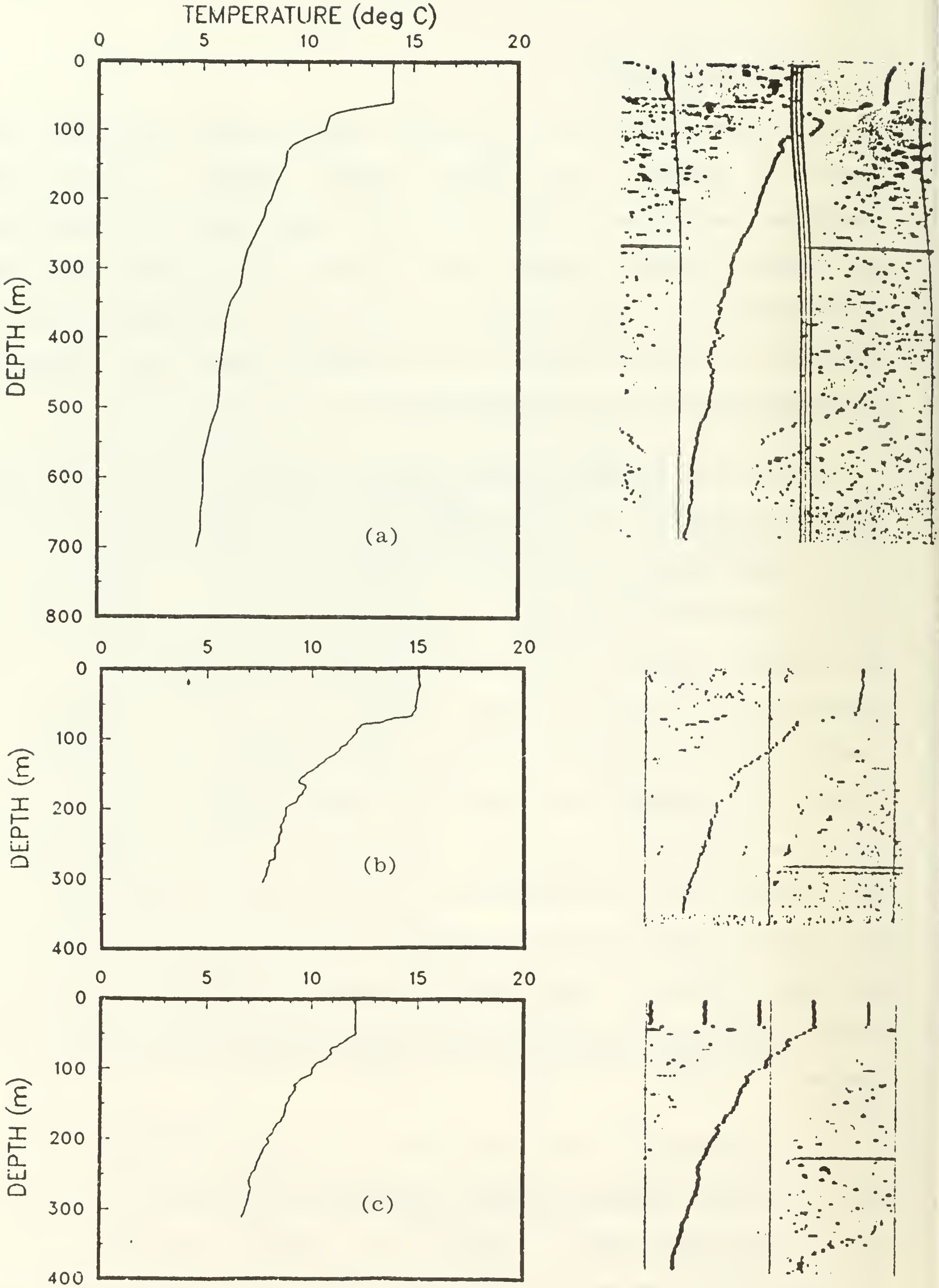


Figure 11 : (a) Hand-digitized representation (L) of lofargram trace (R) (OPTOMA3 ; 35 points),
(b) SIO digitized representation (L) of lofargram trace (R) (OPTOMA11P ; 199 points),
(C) ADAS digitized representation (L) of lofargram trace (R) (OPTOMA15P; 684 points).

to include additional microprocessors and a MK9 unit, development of an NPS airborne DAS became economically feasible. Additional particularly attractive considerations were that the data could be stored in digital format and processed in real-time, and that the data would be in the standard OPTOMA format for ready use in existing computer software. A decision was made to fabricate a system with the following attributes: (1) there should be minimal capital outlay through optimum usage of current project hardware, (2) the system should be self-contained, portable, and have its own navigation capability, (3) the system operation and software execution should be straightforward enough to permit easy operation by anyone, (4) there should be an independent backup system in case of catastrophic failure of the ADDAS, and (5) if possible, the system should allow multichannel recording. The ADDAS, which satisfied items (1) through (4), was assembled and programmed in time for OPTOMA13P. Upgrades necessary for multichannel recording (Item 5) are now being examined (see Part Two for details).

The OPTOMA13P mission was flown by a reserve squadrons VP91 and SAU0617 stationed at Moffett Field, CA. Approval for an NPS observer to participate on the flight was not received; therefore, a naval officer, who had previous experience with oceanographic AXBT missions, was recruited to operate the ADDAS.

The flight was executed as planned (see Figure 12) except that the station spacing had to be increased from 37 km to 46 km in order to avoid transmission interference from successively deployed AXBTs. Hence, only 55 AXBTs were deployed in the NOCAL domain instead of the 68 planned. A deep AXBT was launched at each station but the data only recorded to 305 m. The aircraft maintained an altitude of 3000 to 4000 ft and an airspeed of 170

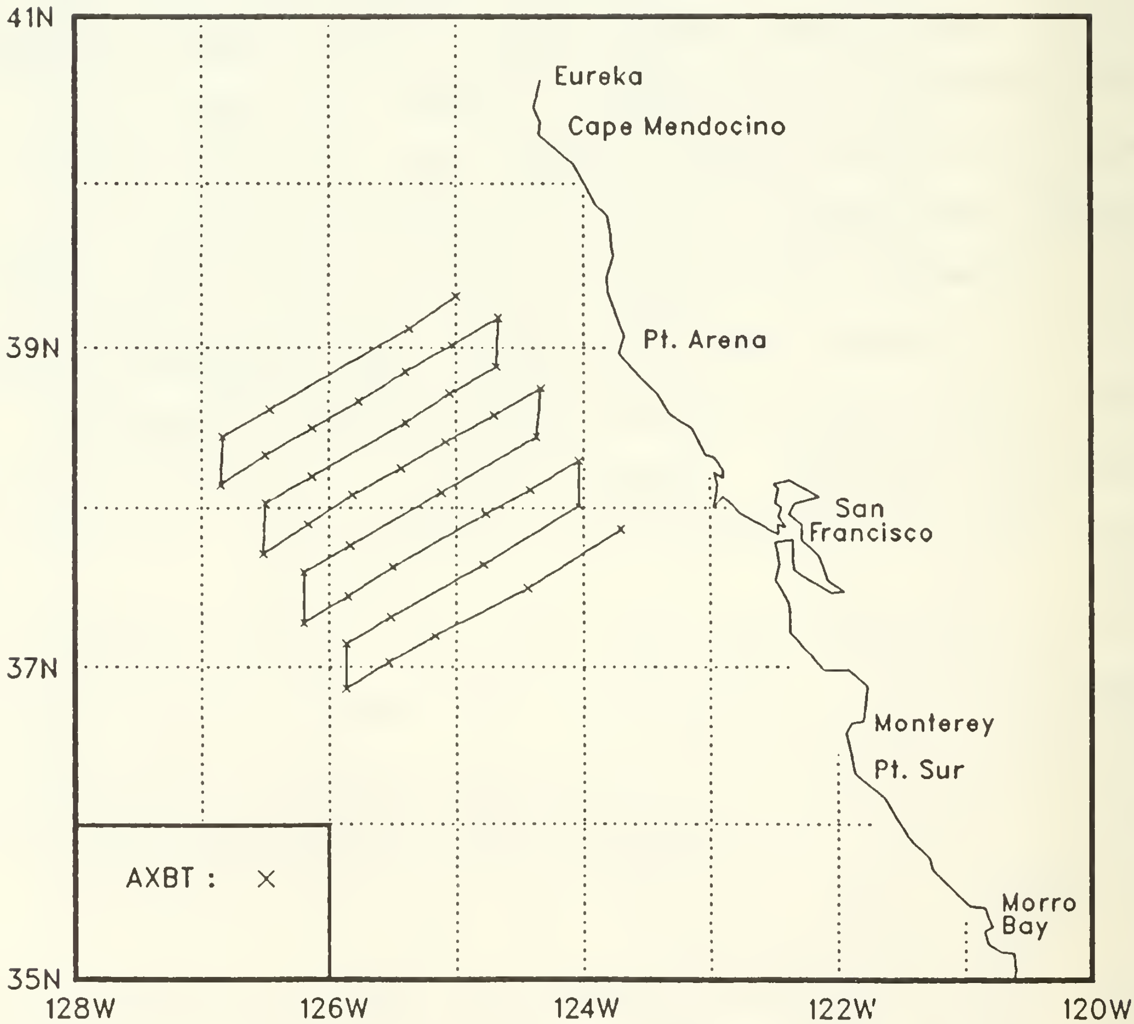


Figure 12: Flight track and station positions for OPTOMA13P.

to 195 knots during the drops. On this flight, the aircraft's INS was used to determine station positions.

Of the 55 AXBTs deployed, the first four profiles were not stored on diskette due to a logical error in the printing portion of the AXBT software. The error was avoided in the remaining drops by simply choosing not to make a plot of the profiles. The four missed stations were replaced in the grid on the homeward leg of the mission. The software error was corrected postflight and it has not recurred. Seven AXBTs did not transmit an RF signal and one more, which was edited postflight, had a weak wavering signal. The final failure was due to a pre-triggering error in the MK9 (once the system is readied for launch and waiting for the AXBT signal, it is susceptible to interference on the receiving channel). In this case, local radio traffic on channel 14 triggered the profiling sequence just before the launched AXBT impacted the water surface. The profile was not lost, however, as it was successfully recorded on the audio cassette tape for postflight playback through the ADDAS. In all, 42 profiles were recovered, yielding a retention percentage of 83%.

The major lesson learned on this flight was that the long transmission times and the associated wide station spacing of the deep AXBTs reinforced the need for a multichannel digitization system. Reducing the speed of the aircraft to compensate for the longer times is not a satisfactory compromise as it reduces the areal coverage of the survey. However, setting aside the multichannel issue (and the minor software error), the first test of the ADDAS was successful. Its 'easy to operate' attribute was proven by the fact that the system was operated by non-NPS personnel on its maiden flight.

In the OA map of the sea surface temperature, Figure 13, there was a positive offshore gradient in temperature from an inshore minimum of approximately 13C to an offshore maximum of 17.6C.

At least three pairs of equations exist for the conversion of audio frequency to temperature and the calculation of depth for a given point from the known fall rate of the AXBT probe. Bane and Sessions (1984) intercompared AXBT profiles computed from each of the three sets of equations (Navy, Sippican, Gent) against simultaneously obtained CTD profiles. The objective was to determine the most accurate set to use when deploying deep preproduction AXBTs (those manufactured by Sippican in 1980 under contract number N00163-80-C-0134). The results indicated that dependable results could be obtained by using the Navy depth equation and the Gent temperature equation.

In OPTOMA13P, preproduction deep AXBTs were deployed; thus, to assess the impact of the differing equations on the resulting temperature fields the OPTOMA13P data were reprocessed using the Gent equation and the Navy depth equation. At each station, the profiles produced from the two sets of equations were differenced and a mean difference profile computed. The Sippican produced temperature profiles were on average +0.4C warmer throughout the water column than the profiles produced by the Gent equation.

On 27 October, there were three AXBT deployments which were within km and a few hours of XBT casts made by the NOAA ship MCARTHUR. Th XBT profiles were compared to the AXBT profiles produced from the two set of equations. From this nonideal, small sampling, it was concluded that th Gent equations were more consistent with the XBT profiles especially in th mixed layer. As in the Banes and Sessions study, a +0.4C warm bias wa

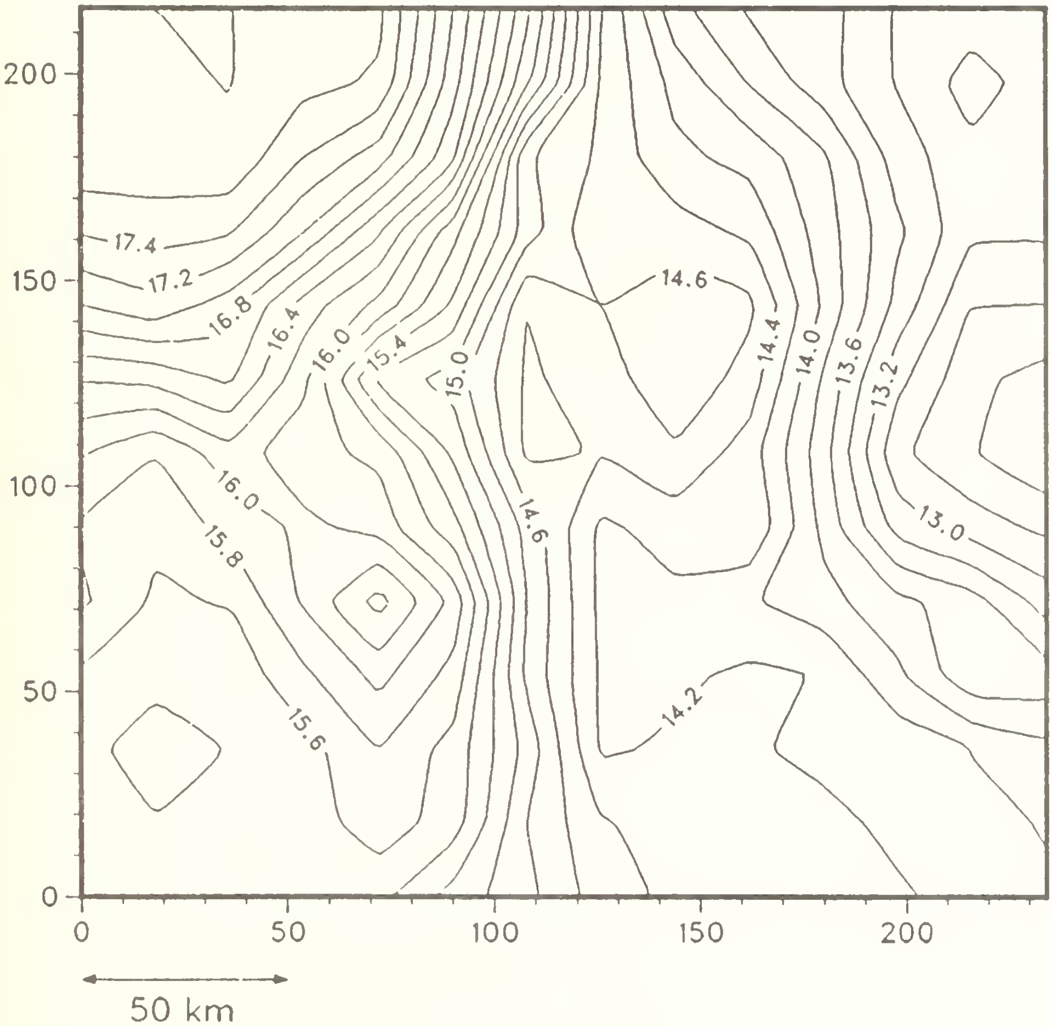


Figure 13: Objective analysis of sea surface temperature (OPTOMA13P).

observed in the Sippican temperature profiles. However, because of the small sample size it was decided to continue processing the AXBT data with the Sippican equations until further test cases could be added to the sample. The OPTOMA15 data set is now being examined for additional XBT/AXBT pairs. In the future, flights which occur within a research cruise period shall include plans to rendezvous with the ship (optimal case) or, at least, to deploy AXBTs along the most recent cruise track.

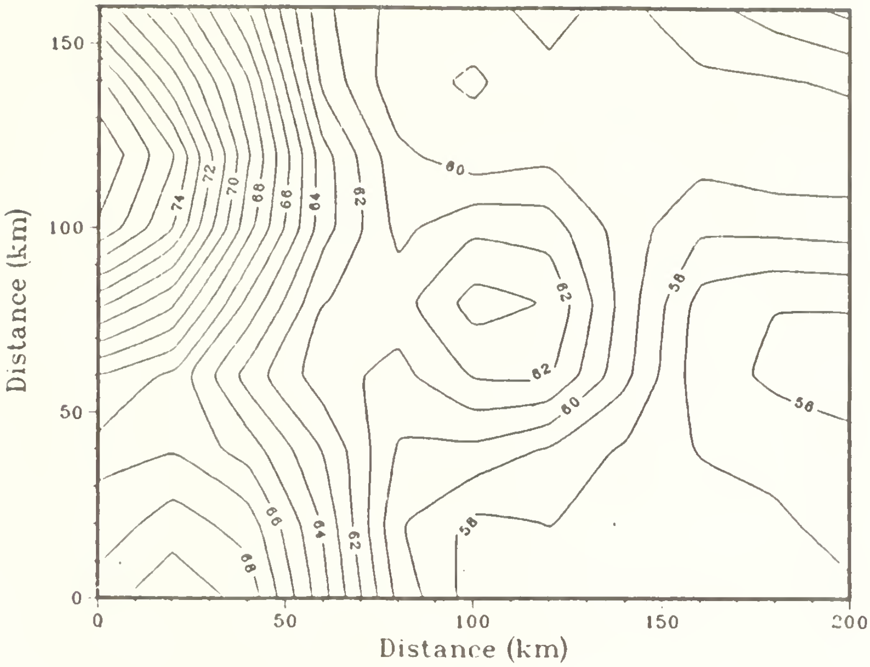
The equations now used in the MK9 software are:

$$D = 1.554602 * t - 1.634E\text{-}4 * t^2 \quad (3),$$

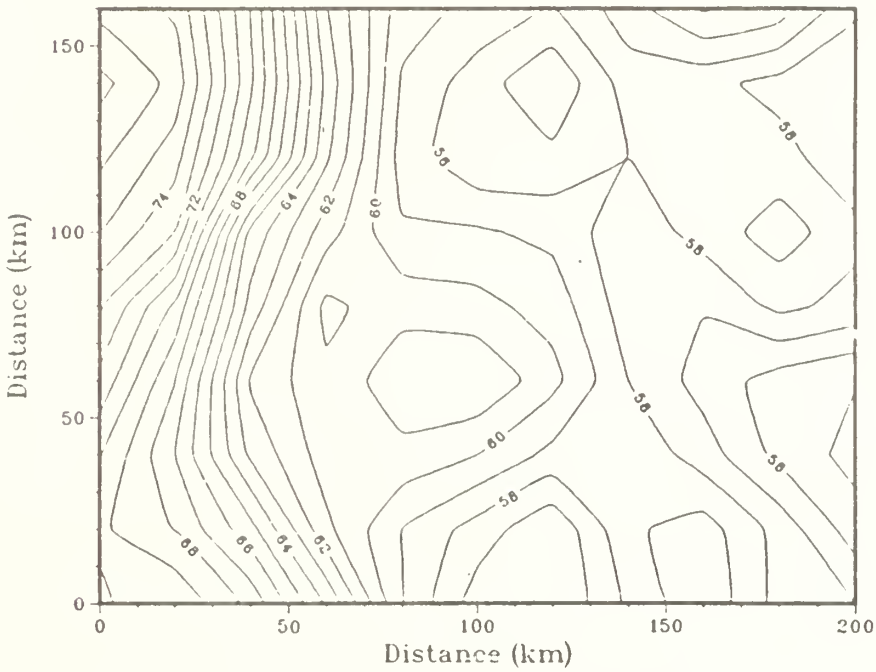
$$T = -126.662 + 0.219954 * F - 1.705096E\text{-}4 * F^2 + 7.70534E\text{-}8 * F^3 - 1.7958E\text{-}11 * F^4 + 1.73823E\text{-}15 * F^5) \quad (4),$$

where, D = depth in meters, t = elapsed time in seconds after probe release, T = temperature in degrees Celsius, and F = frequency in Hz. The depth equation (3) was adjusted from that previously used by Sippican, subsequent to Bane and Sessions (1984). These adjusted equations were used to process the data from flights OPTOMA11P, 13P, and 15P.

Salinity profiles for the AXBTs were estimated from the CTD data acquired during the quasi-synoptic cruise, OPTOMA13, in order to calculate dynamic heights relative to 300 m. The dynamic height field, Figure 14(a), is dominated by a southward current in the center of the domain and a large (100 km diameter, 7 dyn-cm range) anticyclone in the northwest quadrant. Two smaller anticyclonic features (50 to 100 km diameter, 2 to 4 dyn-cm) are also present: one near the center of the domain on the inshore side of the current, and the other on the offshore side of the current in the southwest quadrant. This map is consistent with the equivalent version produced from



(a) OPTOMA13P



(b) OPTOMA13 (22 Oct to 2 Nov 84)

Figure 14: (a) Objective analysis of AXBT surface dynamic height relative to 300 m (OPTOMA13P).
(b) Objective analysis of XBT/CTD surface dynamic height relative to 300 m (OPTOMA13).
The analysis domains were adjusted to include only that area common to both mappings (see Appendix B, Fig. B-4)

shipboard observations, Figure 14(b). To compare the fields, the domain size was reduced to 200 by 160 km so as to include only that area common to both mapppings (see Appendix B, Fig. B-4). All of the primary discrepancies, viz.: (1) the alignment of the large anticyclone, (2) the absence of the smaller anticyclone in the XBT/CTD field, present in the southwestern quadrant of the AXBT field, and (3) the orientation of flow in the northeastern quadrant of the AXBT field can be attributed to the absence of data from the shipboard survey (1 and 2), or the airborne survey (3), when the contoured fields are produced from extrapolation of the existing data. From this initial comparison, it appears that the hydrographic data acquired over a twelve day period could be considered to yield a fairly valid description of synoptic fields.

E. OPTOMA15P (27 Jan 85)

This flight was flown on 27 Jan 85 by reserve squadrons VP91 and SAU0617. Ms Colton (NPS) acted as the scientific member of the crew and operated the ADDAS.

On this mission, the NOCAL area was to be sampled as a series of concentric squares, shrinking in size from the outermost square, 140 nm (260 km) on a side, to the innermost square, 60 nm (111 km) on a side. Sixty-eight AXBT stations were planned. The planned station spacing between deployments was not as regular as usual due to the staggered use of shallow (305 m) AXBTS and deep (760 m) AXBTs. The shallow probes require at least five minutes or 28 km for completion of data transmission and data storage; the deep probes require at least 9 minutes or 46 km. This plan was nearly accomplished, Figure 15, but slower-than-planned airspeed (160 knots) and the necessity to return to base early to meet an airlift schedule did not permit completion of the innermost square.

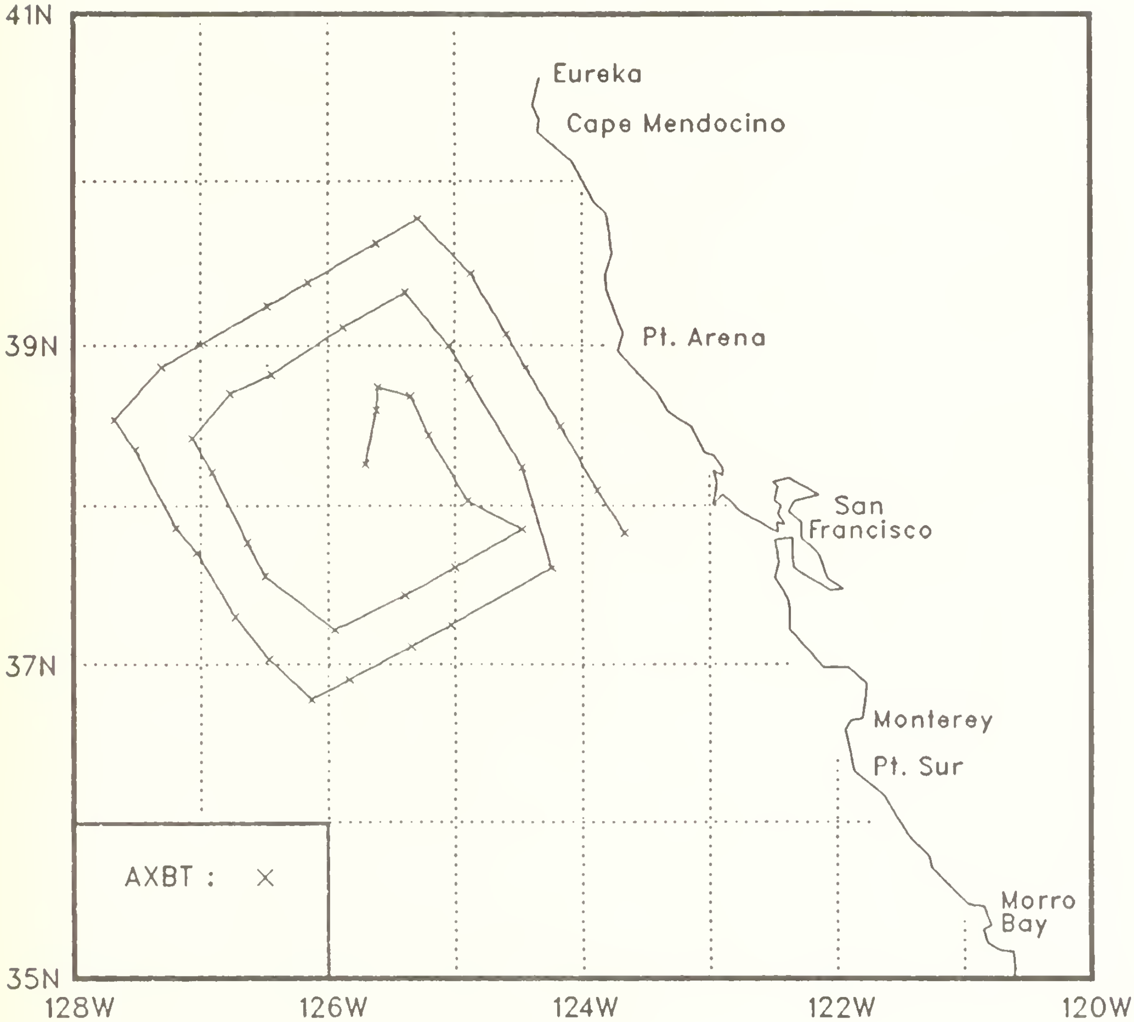


Figure 15: Flight track and station positions for OPTOMA15P.

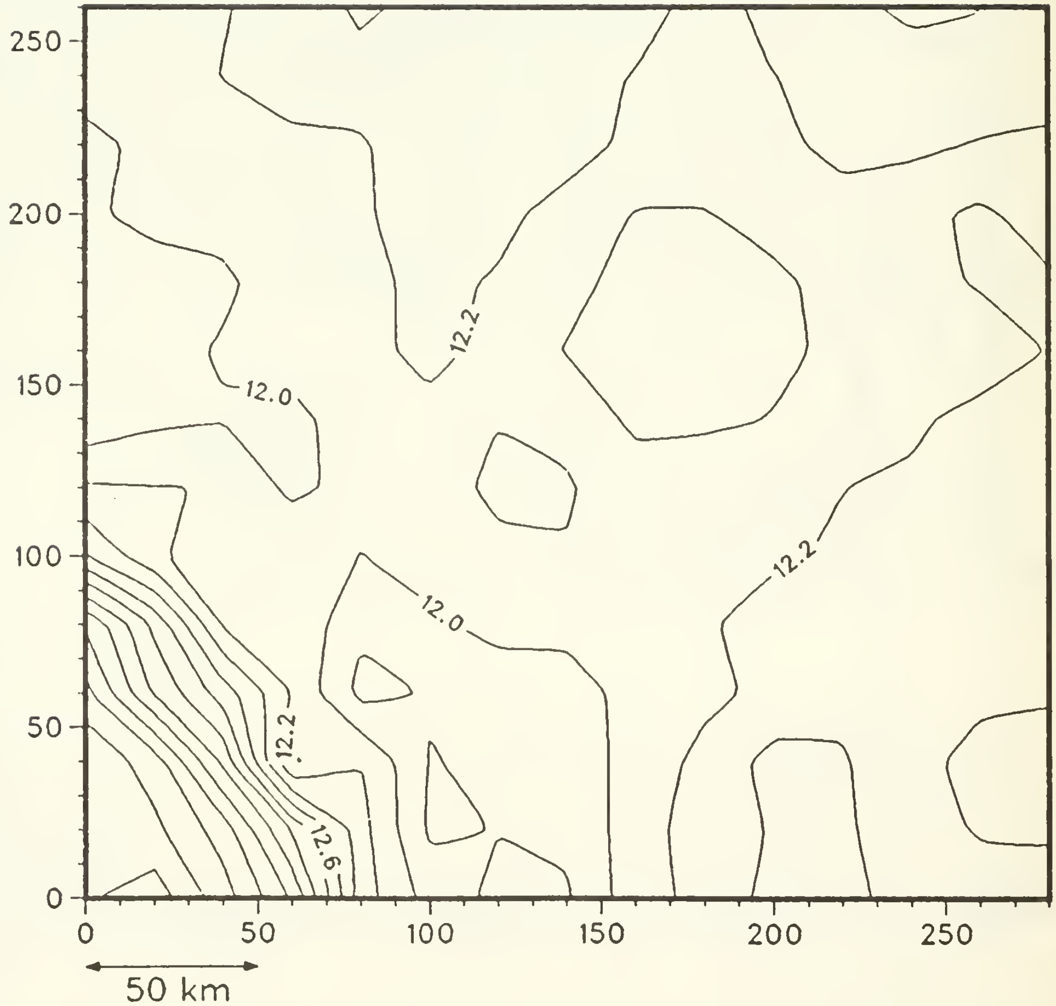


Figure 16: Objective analysis of sea surface temperature (OPTOMA15P).

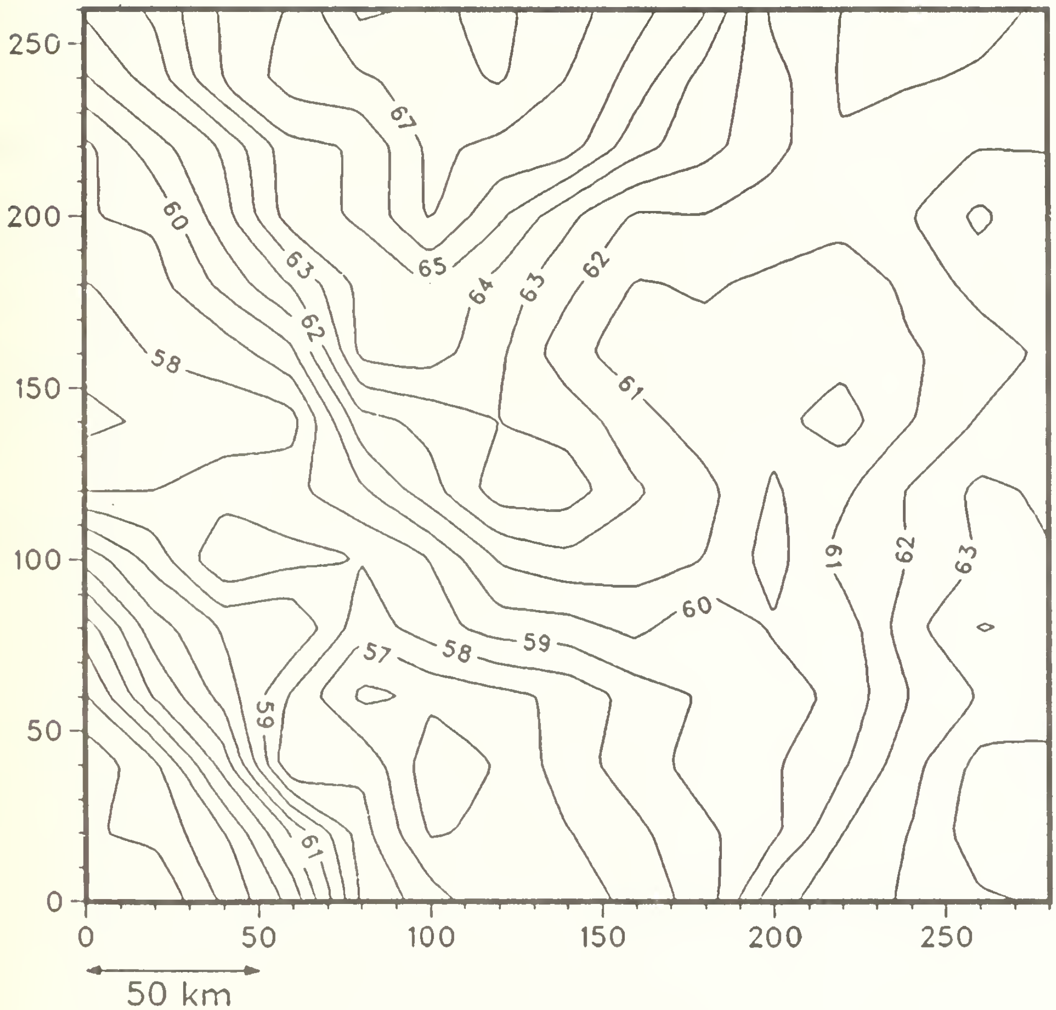


Figure 17: Objective analysis of surface dynamic height relative to 300 m (OPTOMA15P).

In all, 50 AXBTs were deployed and 44 acceptable profiles recovered. There were six failures: five due to instrument malfunctions resulting in no RF transmission and one due to a pre-mature triggering of the MK9 (a strong transmission on Channel 14 in the southeast corner of the domain consistently triggered the MK9, thereby prohibiting the use of any Channel 14 AXBTs in this region).

The dominant feature in the SST map, Figure 16, is the strong offshore temperature gradient (approximately 1.4C in 40 km) observed in the southwest corner of the domain. The remainder of the SST field is essentially flat, displaying only an approximate 0.6C range (11.6 to 12.2C) over roughly 90% of the domain. The warmer temperatures in the north and cooler temperatures in the south, near the front, are consistent with the larger scale weak anticyclone and cyclone, respectively, apparent in the surface dynamic height map, Figure 17. There is a seven dyn-cm offshore gradient in the dynamic height in the southwest corner of the domain. This gradient is perpendicular to the SST front, and it is indicative of a southeastward current.

Tables I and II summarize the operational specifics and the AXBT statistics, respectively, of the OPTOMA flights to date. Table III summarizes the oceanographic characteristics observed in, or computed from, the AXBT temperature fields.

FLIGHT	DATE	DOMAIN	DURATION (hours)	SQUADRON	FLIGHT OBSERVER	AIRCRAFT ALTITUDE (feet)	AIRCRAFT SPEED (knots on stn)	NAVIGATION	DATA ACQ. METHODS	DIGITIZE METHOD	POINTS PER PROFILE	ACCURACY
3	10FEB83	CENCAL	8	VP147 (active)	LT Williams (NPS)	1500	210	INS TACAN RADAR	Analog Traces	Gridded Template	15 to 20	Depth ±6.25m Temp ±0.40C
8	10DEC83	NOCAL	9	reserve	NONE	1000	230	INS TACAN	Analog Traces Onboard Recorder	HP Digitiz. Pad NAVOCEANO	15 to 20	Depth ±6.25m Temp ±0.40C
	15DEC83	CENCAL	9	reserve	NONE	2000 to 3000	230					
11P	18JUL84	NOCAL	9	VP65 (reserve)	M.H. Sessions (SIO)	1500	230	RADAR TACAN	Analog Traces Audio Cassette	SIO DAS	200	Resolution Depth ±1.5m Temp ±0.03C
13P	27OCT84	NOCAL	9	VP91 SAU0617 (reserve)	LT Johnson (Moffett)	1500	170	INS TACAN	Analog Traces Audio Cassette 3½" Diskette	ADDAS	684	Depth* 2% or 5m Temp ±0.18C
15P	27JAN85	NOCAL	8	VP91 SAU0617 (reserve)	M.C. Colton (NPS)	1500	170	INS TACAN	Analog Traces Audio Cassette 3½" Disk	ADDAS	684	Depth* 2% or 5m Temp ±0.18C

* whichever is greater

TABLE II: OPERATIONAL SPECIFICS OF THE OPTOMA FLIGHTS

FLIGHT	DATE	DOMAIN	AXBTS Planned / AXBTS Deployed	Planned Spacing / Actual Spacing km	Failures / Edits** Postflt	Per cent Failures / Per cent Recovery	MANUFAC.	CONTRACT	CHANNEL	DEPTH	Number of each Deployed
3	10FEB83	CENCAL	72	28	8	11%	SIPPICAN	UNKNOWN	14 14	305m 760m	19 16
			70	28	1	87%			16 16	305m 760m	12 17
8	10DEC83	NOCAL	68 / 62	40 / 40	1 / 1	2% / 97%	SIPPICAN	UNKNOWN	12 14	305m 760m	49 36
	15DEC83	CENCAL	68 / 61	40 / 40	5 / 1	8% / 90%			16	760m	38
11P	18JUL84	NOCAL	68	36 to 52	6	9%	SIPPICAN	UNKNOWN	14	305m	35
			66	35	3	87%			16	305m	31
13P	27OCT84	NOCAL	68	37	7	13%	SIPPICAN	N00163-80-C0134	14	760m	24
			55	46	2	83%		N00163-80-C-0134	16	760m	31
15P	27JAN85	NOCAL	68	28	6	12%	SIPPICAN	N00163-78-C-0112	14	305m	24
			50	28 to 46	2	84%		N00163-81-C-0287	16	760m	26

**Profiles are deleted on the basis of erroneous temperatures, excessive noise, offsets due to start time delays, and suspicious 'shapes'.

TABLE III: OCEANOGRAPHIC CHARACTERISTICS OBSERVED IN OR COMPUTED FROM THE AXBT TEMPERATURE FIELDS

FLT	DATE	DOMAIN	DYN HT RANGE (dyn-cm)	TEMP RANGE (deg C)
OPT3	10 FEB 83	CENCAL	17	12.5 to 15.5
Major Features: Northeastward (onshore) current; cyclone in NW.				
OPT8	10 DEC 83 15 DEC 83	CENCAL NOCAL	20	13.0 to 15.9
Major Features: Inshore weak cyclone with southward jet along offshore edge, anticyclone in NW, eastward current along bottom edge of domain.				
OPT11	18 JUL 84	NOCAL	23	12.6 to 15.5
Major Features: Westward jet deflected to the south by anticyclone in the NW, cyclone in the SE,				
OPT13	27 OCT 84	NOCAL	20	12.1 to 17.8
Major Features: Southward current in center of domain, anticyclone in the NW; two smaller anticyclones inshore of jet and one anticyclone offshore in SW quadrant.				
OPT15	27 JAN 85	NOCAL	10	11.6 to 14.6
Major Features: 1.4C temperature gradient in the SW corner of domain, large-scale weak anticyclone in north, central domain and weak cyclone in south, central domain.				

PART TWO: DESIGN AND OPERATION OF THE ADDAS

III. NPS PROTOTYPE ADDAS

A. *Hardware*

The ADDAS consists of the following components: (1) an HP9816 MC68000 16-bit microprocessor with HP9121 3.5 inch microfloppy dual disk drives, (2) a Sippican MK9 front-end processor (digitizing unit), (3) an ARNAV-R40 LORAN-C unit, (4) a Sony DM6-C tape recorder (monoaural, to be replaced with a stereo recorder), (5) a Tektronix Type 321A oscilloscope (to be replaced with a smaller Tektronix-211), and an HP Thinkjet printer (to be replaced with a HP-7470A two-pen plotter). Power for the system is obtained by inverting 28VDC power to 115V, 60 Hz via a static inverter manufactured by Avionic Instruments Inc. (model 2A125-1A).

B. *Software*

The data acquisition software, written in HP Basic 3.0, is a streamlined version of the shipboard XBT data acquisition software. Portions of the program which relate to the MK9 unit were adapted from the Sippican MK9 software written for the HP9845 microprocessor (Sippican manual, 1983). To make the AXBT profiles appear like the XBT profiles for input into the OPTOMA data processing software, the audio frequencies are averaged to make the profiles a standard 684 points in length (the background for this standard format is given in Appendix C). With a sampling interval of 0.1s, a shallow AXBT which transmits for approximately 205s will consist of about 2050 points; therefore, the averaging interval needed to reduce this figure to 684 points is 0.3s, (3 points). In the case of a deep AXBT, nearly 5000 frequency values are transmitted; therefore, an averaging interval of 0.7s (7 points) is used. The maximum profile depths obtained for the shallow AXBTs is 305 m and for the deep AXBTs it is 760 m. The accuracy of the temperature measurement is +0.18C and the accuracy of the depth measurement is ±5 m, or 2% whichever is greater.

The ADDAS program is driven from a 'menu' which has the following options:

1) Plot AXBT - allows plotting of any AXBT on any disk

2) Change time and date - (executed once per flight before first station)

3) Catalog data disk - allows review of contents of any disk

4) MK9 AXBT - prepares system for deep or shallow AXBT deployment.

When an option is selected, prompts are displayed which step the user through the inputs required for that option. Detailed instructions, and a program listing are provided in Appendix C.

C. Installation of the ADDAS

1) In the portable rack

The ADDAS components are mounted in a 22" X 22" X 30" half-rack as shown in Figure 18. The MK9 unit is held in place by two rack mounting brackets and four flat-head screws. The oscilloscope, disk drive, and LORAN unit are stacked on top of the MK9 with firm packing foam between them for protection and immobility. The Thinkjet printer is set up on the sensor station counter after takeoff so that there are no obstructions in the paper-feed path. (These somewhat temporary arrangements were considered acceptable for the prototype ADDAS since the system was usually dismantled immediately after each flight for use of the components in other projects; more frequent flights will mandate more secure installation methods.) The HP9816, keyboard and tape recorder are placed on top of the rack and are wedged between wooden blocks for lateral stability. Vertical motions of these components are restricted by

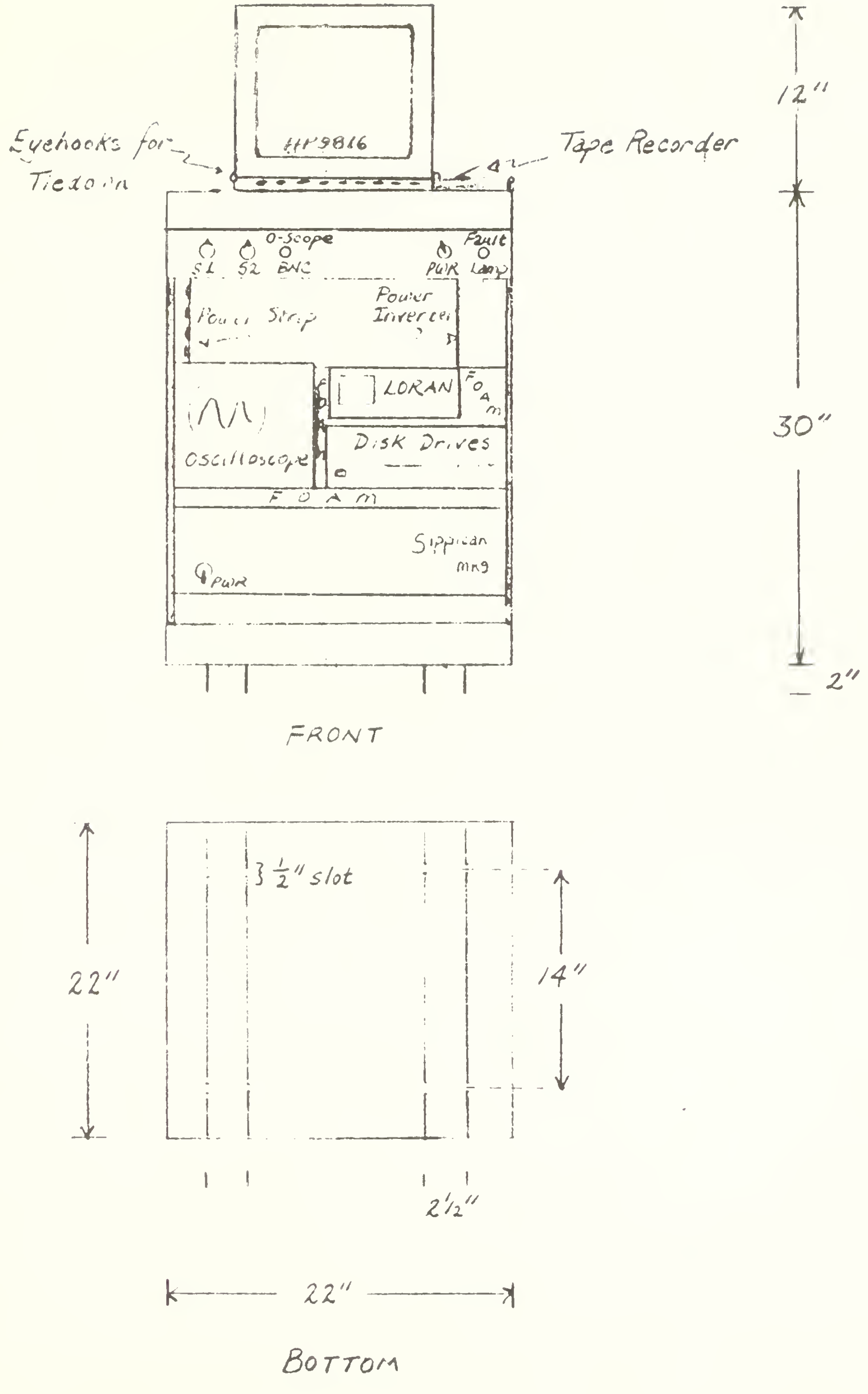


Figure 18: ADAS component installation in portable rack.

stretching tubing over them and anchoring the tubing to eyebolts, which are screwed into the plywood on top of the rack.

The power inverter bottom surface is coated with thermal conducting grease and the inverter mounted to a 12" X 24" X 1/8" aluminum baseplate, which acts as an external heat sink. The assembly is then bolted to the rear, right side of the rack. The input to the inverter is a 10 AWG, 15 ft long cable soldered to a pin connector on the front plate of the inverter. On the airframe end of the cable are input and ground spade-type terminal lugs. The output to the system is a 18 AWG, 3 ft cable with a female plug on the system end. The toggle switch on the right side of the system control panel allows 28VDC aircraft power to reach the inverter only. The lamp next to this switch glows when the inverter is operating normally.

The power strip on the rear, left side of the rack plugs into the output cable of the inverter. All of the system components, except the tape recorder which is battery operated, then plug into the strip. For electrical protection, a switch on the strip isolates the system from the inverter. Each component has its own power switch, thus a third level of power isolation is achieved.

Six cables (two per channel) with test lead connector pins extend from the two rotary switches labelled MK9 and RECORDER (S1 and S2 in Figure 18) on the left side of the control panel to the sonobuoy interconnection box. Any one of three channels may then be selected and recorded by the MK9 or recorder. The oscilloscope receives its input signal at the BNC connector just to the right of these switches on the control panel.

Finally, communications between the HP9816, disk drive, MK9 and printer are accomplished through IEEE488 HP interface busses.

2) In the aircraft

The installation and checkout of the ADDAS in the aircraft requires approximately one hour.

a) Mechanical connections

Safety regulations for the P3 require that all extra equipment brought onboard the aircraft must be securely fastened for takeoff (and preferably, for the duration of the flight). To satisfy this requirement, the ADDAS is attached to the sensor station seat rails. The seat rails are two 1 inch high, 1 1/8 inch wide I-beams spaced 14 inches apart, which run parallel to the sensor stations. One-quarter inch holes spaced one inch apart allow the seats mounted on the tracks to slide to any position and to be locked into place. To mount the ADDAS on the rails, two segments of 2 X 2.5 inch u-channel are bolted to the bottom of the half-rack, Fig. 18 (the oversize channel was chosen so as to avoid scratching the sliding surfaces of the rails). Two 1/2 inch slots are drilled 14 inches apart in each segment; the extra 1/4 inch allows for slight misalignment of the seat rails. Four pairs of 1/4 inch bolts and nuts, with 2 washers each, are inserted through the seat rail holes, securing the ADDAS.

b) Electrical connections

The 28VDC aircraft power supplied to the ADDAS is that which is delivered to Sensor Station 2. To access this power, the input terminal lug is connected to terminal A24 on terminal board TB431 above Sensor Station 2 (see Figure 19 and Plate 1); the ground terminal lug is connected to a stud on the far right side of the terminal board. The 10 amp circuit breaker for Sensor Station 2 is on the center electrical circuit breaker panel located just inside

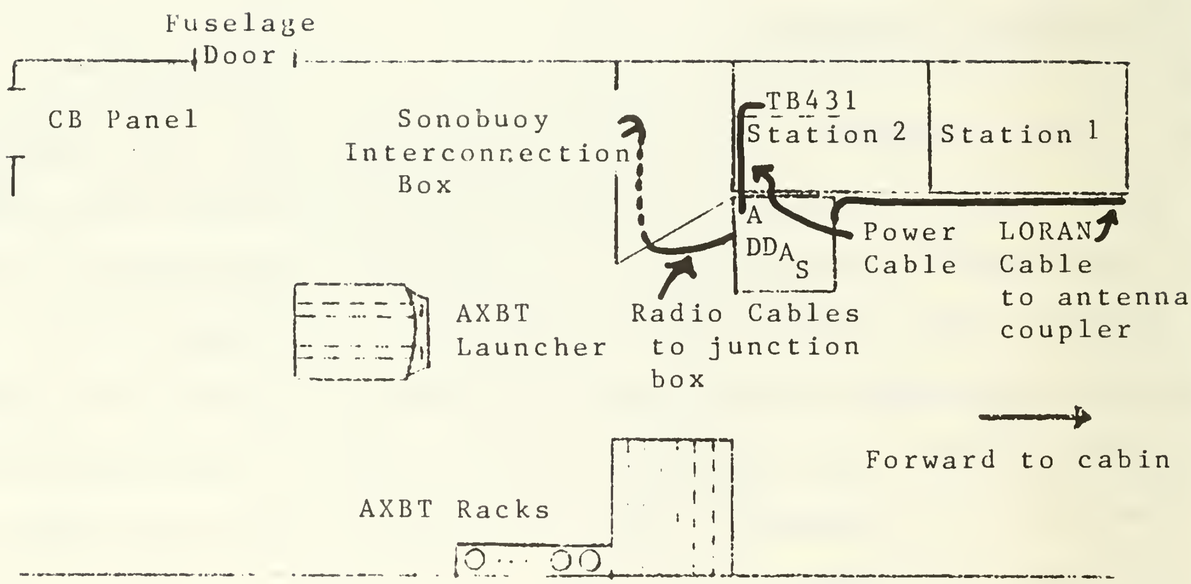


Figure 19 : Electrical installation schematic of ADDAS in aircraft.

Plate 1: Installation photograph of the ADDAS at Sensor Station 2.

and aft of the fuselage door.

The six receiver cables of the ADDAS are routed beneath the triangula partition aft of the ADDAS, then up to the sonobuoy interconnection bo located on the mid-fuselage bulkhead. At present, only four of the six cable are connected on each flight; the remaining two allow for expansion to third channel AXBT. The test points used at the junction box are Standar Audio pins numbered 4 through 7; these pins correspond to channel selec switches A through D at Sensor Station 1. To minimize confusion, th channels are selected at the Sensor Station so that A through C on th ADDAS rotary switches MK9 and RECORDER correspond to A through C on th channel selects; i.e.,

Pin 4: Plug in 'A' lead from ADDAS; select channel 14 at Sensor Station 1

Pin 5: Plug in 'B' lead from ADDAS; select channel 16 at Sensor Station 1 channel select 'B',

Pin 6: Plug in 'C' lead from ADDAS; select third channel at Sensor Statio 1, channel select 'C'.

The final connection required is the antenna cable connection to the LORAI unit. The antenna cable is routed forward approximately 25 ft to the antenn coupler BNC connector loacted in the port electronics bay just forward of th RADAR sensor station. A preamplifier is placed in-line six inches from th coupler to boost the signal to the LORAN. For safety purposes, the cable i run overhead of the stations and secured wherever possible with plastic tie wraps.

E. Operational usage

To understand better the operation of the ADDAS, Figure 20 illustrates a AXBT deployment. The following paragraph from Bane and Sessions (1984 describes the major events of the deployment sequence:

> An AXBT package is generally deployed top-end first from a chute in the lower rear of the aircraft's fuselage (Plate 2). As the AXBT leaves the aircraft, the spring-loaded wind flap separates from the package body and pulls out the cross-type parachute. The parachute stabilizes the package in an upright position and controls the speed of the package during descent to the ocean's surface. After water impact the seawater battery activates and turns on timing circuitry, which triggers a mechanism to inflate the floatation bag. As this bag inflates it forces a plate out of the outer cylindrical housing allowing the parachute and the outer housing to be discarded. A smaller cylinder containing the battery, electronics, floatation bag, and XBT probe with wire and spools remains at the ocean's surface. The VHF transmitter is turned on and sends an unmodulated RF signal to the aircraft on one of three possible VHF carrier frequencies (170.5, 172.0, and 173.5 MHz). Approximately 40 s after battery activation, the XBT probe is released from the small cylinder and begins temperature profiling. Temperature is converted to an audio-range frequency in the probe; that frequency is transmitted up the hard wire link to the surface electronics; then the RF carrier is modulated with the audio frequency. Probe descent time is later converted to depth and audio frequency to temperature to produce a temperature-depth profile by using appropriate formulae. About 1 min after completion of the descent of the probe, a current is sent through a resistive heater wire attached to the inside of the floatation bag causing it to puncture, thereby allowing the package to sink.

The RF modulated signal is accessed by the ADDAS at the sonobuoy interconnection box. To record, digitize, and plot each AXBT profile, the ADDAS is operated using the following procedure:

1) Power up system (one time only)

Toggle inverter power switch on the right side of the control panel to 'ON'. When the inverter fault lamp glows, indicating that the inverter is functioning normally, turn on the power strip switch. Next, turn on the individual components in the following order: disk drive, CRT, MK9, oscilloscope, LORAN, and after takeoff, the printer.

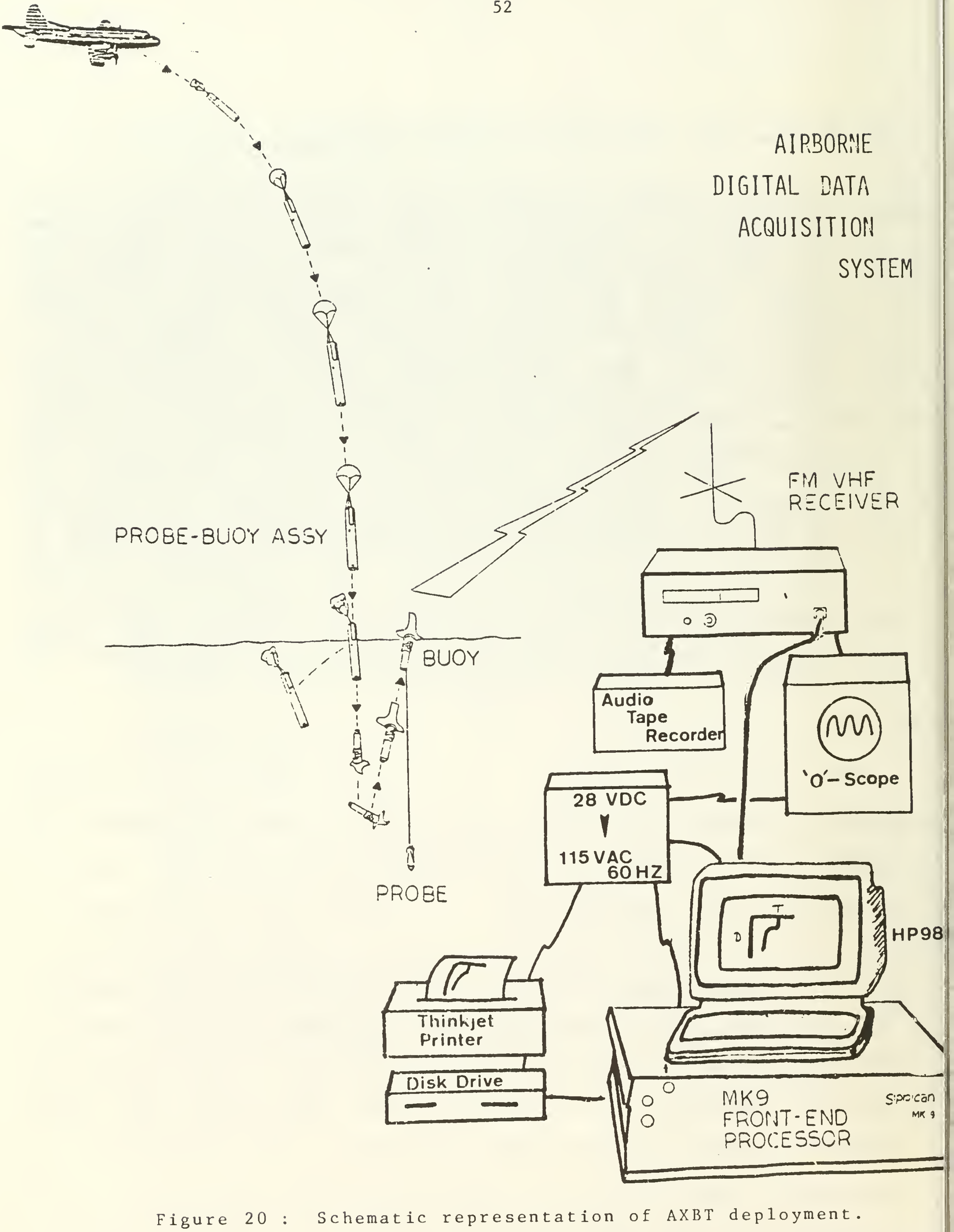


Figure 20 : Schematic representation of AXBT deployment.

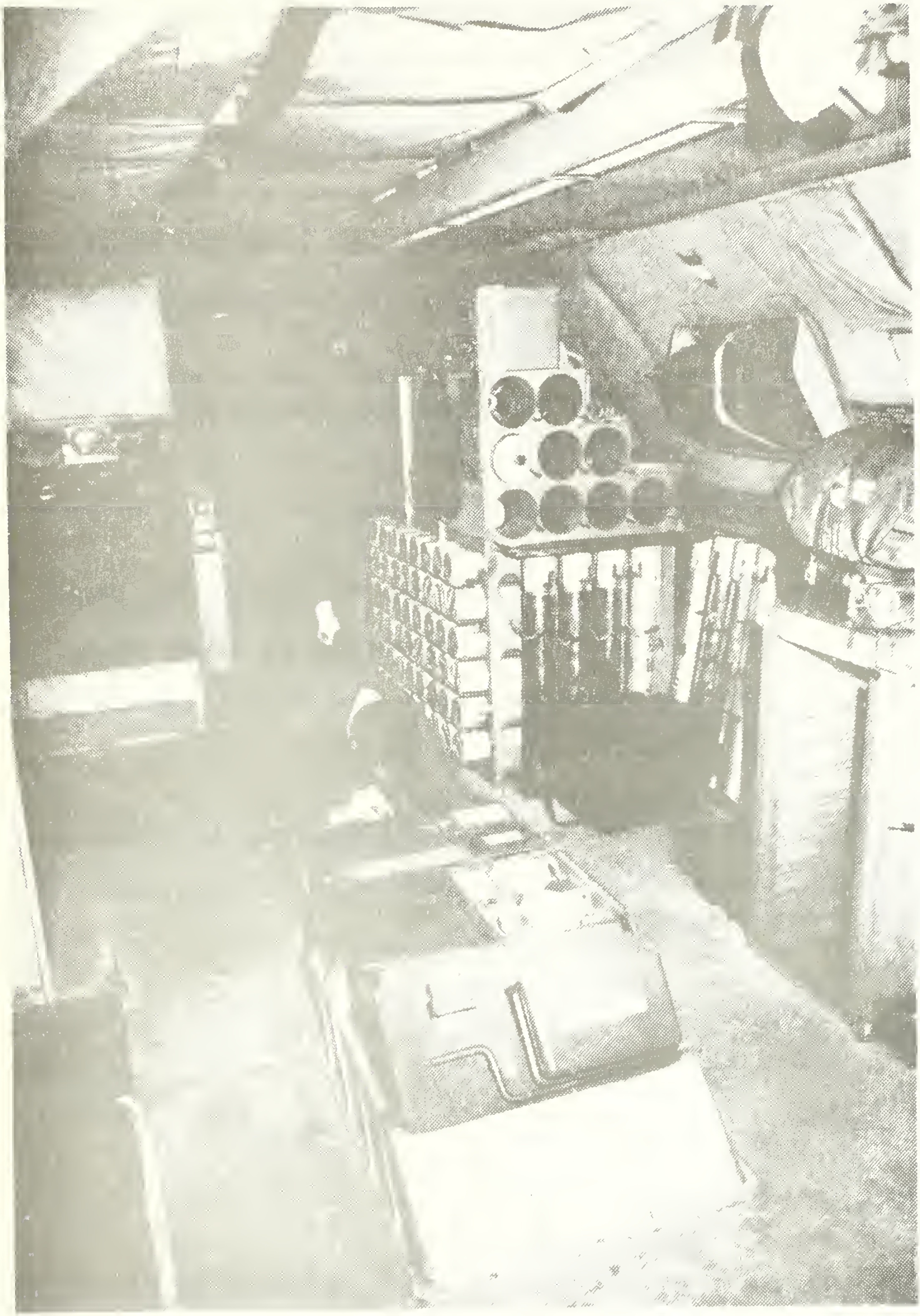


Plate 2[illegible] [illegible] and stowage racks in the [illegible]

2) *Initialize the HP BASIC operating system and load the AXBT program (one time only or after power failure)*

a) Insert the BASIC(SYS) disk in left disk drive and the BINARIES disk in the right disk drive.

b) Press the Shift and Reset/Pause keys to trigger system memory check.

c) When BASIC Ready appears, remove the system diskettes.

d) Insert 'AXBT' diskette in the left drive.

e) Type LOAD "AXBT", press Execute, then Run.

f) Remove AXBT diskette from left disk drive.

g) Insert data diskette into right drive.

3) Press the 'k0' programmable key to display the 'Menu'. Select option '4' (MK9 AXBT) to prepare the computer for an AXBT launch (see Appendix A). If the graph and 'Clear to launch' cue do not appear, cycle the MK9 power switch to reset the I/O interfaces.

4) Set rotary switches on the control panel to the appropriate channel position for the next AXBT to be launched, e.g., 'A' for channel 14, 'B' for channel 16.

5) Complete the station log sheet. The log sheet has columns for entries of channel number, station number, time, latitude, longitude, audio cassette number and tape position counter, and comments.

6) Start the tape recorder.

7) Start the lofargram recorder (done one time only).

8) Inform the crew over the Intercommunications System (ICS) that all is prepared for the next launch; launch the AXBT.

9) To listen for the start of the AXBT audio signal, select the radio receiver mode on the ICS mode switch above Sensor Station 2. About 40 sec after the beginning of the signal the probe should deploy. Watch for evidence of this on the CRT, on the lofargram, and on the oscilloscope, which should display a sinusoidal waveform. Note failures and weak signals on the log sheet.

10) At the end of the profile: 'PAUSE' the tape recorder, make a hard copy of the profile, store the data, and annotate the lofargram.

Steps 3 through 10 are repeated for each station.

IV. POSSIBLE IMPROVEMENTS TO THE ADDAS

A. *Improvements on the Basis of Human Factors Analysis*

There are some obvious improvements which should be made to the ADDAS to make it more manageable and portable. A 'custom-made' rack or box needs to be designed that includes shelving or brackets on which to mount the ADDAS components. Carrying handles on the sides of the rack would make transportation of the system easier and safer. There should also be a door or covering which can be latched onto the front of the box to protect the installed components from accidental damage and the weather. A small bracket on which to coil extra cable, mounted on an inside wall, would avoid tangled cables. The four 1/4 inch bolts and nuts which fasten the ADDAS to the seat rails should be replaced with bolts which have detents as it is somewhat difficult to reach under the ADDAS to tighten the nuts. Finally, the LORAN-C panel annunciator light, which flashes within two nautical miles of a waypoint, should be mounted on the ADDAS control panel to warn the operator of an impending station.

B. *Expansion to multichannel recording*

The HP9816/Sippican MK9 single channel system may be expanded to a multichannel system by two methods. The first method, which at present is under development at Sippican, is to program the MK9 units with a selectable IEEE488 HP Interface Bus address. In this way, two MK9 units, each one receiving a single channel, could be differentiated between and responded to by one microprocessor through a single interface connection. The alternate method would be to add a second IEEE488 HP Interface Bus to the HP9816, thus allowing a second MK9 (with the same address) to be attached to the system. In both cases, the HP9816 software would be written to act upon 'interrupts' from the active MK9 unit. The second method could be implemented at NPS since it does not require any modifications to be made to the MK9 circuit board.

Since parallel development of the second method could not be accomplished any sooner at NPS than the date set by Sippican for completion of their upgrade (Fall 1985), a stopgap method will be used in the summer 1985 OPTOMA flight. A stereo tape recorder will record all AXBT deployments. However, to minimize the station spacing, only shallow AXBTs will be recorded and digitized by the MK9 system in real-time. Deep AXBTs will still be deployed; but, since they transmit for nine minutes, they will be recorded only on the tape recorder for digitization by the ADDAS after the flight. The data available in real-time will be comparable in time and spacing to that obtained now, and the addition of the deep AXBTs to the data set after the flight will halve the station spacing and improve the data base.

C. *Software*

The software upgrades to the data acquisition program which will be incoporated in the near future are: the computation and plotting of sound speed profiles using salinity information from the OPTOMA NOCAL domain's mean T vs S curve, and automatic input of latitude and longitude to the HP9816 from the LORAN-C across the unit's RS-232 port.

With the HP9816 microprocessor as part of the ADDAS, numerous applications programs could be implemented. These programs would have to be executed after the final station is completed since the HP9816 is not a multi-tasking machine. However, short programs that provide a 'first-look' at the data could be run on the homeward transect; e.g., an isotherm plottin routine. To improve the quality of the real-time plots an HP7470 two-pe plotter will be used.

On the next OPTOMA flight, an attempt will be made to run the objectiv analysis programs to contour sea surface temperature and depths of the 8(isotherm (with an appropriate selection criterion to define it, the mixed-laye depth could also be contoured). The production of each OA map require about 15 minutes elapsed time; hence, one map, possibly two, could b produced, provided no errors are made, on the homeward transect from th NOCAL domain to Moffett Field, which is approximately a 20 to 30 minut flight. Rather than conflicting with landing procedures, or the offloading of th aircraft after landing, it is anticipated that in these initial attempts, the OA' will be computed after offloading of the ADDAS and reconnection of th microprocessor to ground power. Producing the first-look maps within a fe hours of landing will satisfy the real-time needs of the OPTOMA program an will provide unique post-flight briefing material for the squadrons. It i planned in the next few months to purchase a compiled BASIC, floating-poin accelerator hardware/software package for the HP9816. With this upgrade computations will be performed an order of magnitude faster. Thus, an O could conceivably be completed in about five minutes (elapsed time) on futur flights, thereby eliminating the need for post-landing processing.

V. SUMMARY

The OPTOMA Program goals are to develop an Ocean Descriptive Predictive System for the study and forecasting of ocean mesoscale physics, and to investigate the dynamics of the California Current System. The attainment of these goals requires the establishment of a broad-base ocean observing and monitoring system that provides data from at least the following: hydrographic research cruises, moored arrays, and remotely sensed data. In particular, to forecast the evolution of the oceanic flow field, the observing system must include a means of obtaining real-time, synoptic maps for the initialization and verification of the dynamical model(s) used. Because of their convenience and rapidity, P3 flights to deploy an AXBT grid are a clear choice for frequent mappings of the study domains.

Since February, 1983 six OPTOMA missions have been flown off the California Coast. Of these, four flights have been in the OPTOMA Northern California domain and two flights have been in the Central California domain. A total of 325 AXBTs have been successfully deployed in these regions. Analyses of these data (Part One) reinforce recent discoveries about the character of the California Current System: the current regime is highly variable in nature and it is comprised of cool anomalies, mesoscale eddies, 'squirts' and jets, current filaments and fronts.

The AXBT synoptic maps are of greatest utility to the OPTOMA Program when they can be used in near real-time. To fulfill this need, an Airborne Digital Data Acquisition System was fabricated at NPS (Part Two). This system, which is built around an HP9816 microprocessor and a Sippican MK9 digitizing unit, digitizes the AXBT audio signal, then stores the profiles on diskette. The system was successfully tested on the OPTOMA13P and 15P flights and can now be considered to be completely operational.

With the digital data acquisition problem solved, the open issue is how to exploit fully the aircraft missions. Steps being taken in this direction include expansion of the onboard software library to include 'first-look' data plotting and objective analysis routines, expansion to a suite of aircraft-launched instruments which includes; e.g., expendable sound speed, current, and CTD profilers (to be in production soon), and extension of the ADDAS to a multichannel, multi-instrument recording system.

ACKNOWLEDGEMENTS

As with the development and implementation of any system, there were many active participants in this project who ensured its success by generously giving of their expertise. Each member of the NPS OPTOMA group (Michele M. Rienecker; Edward A. Kelley, Jr.; Paul A. Wittmann) has had input either in the initial software development, or in postflight data editing and analysis. Also at NPS, Messrs. Timothy P. Stanton and James A. Stockel were especially helpful in the electronic integration of the components into a system. Numerous discussions with Mr. Stephan Lamont (NPS Computer Center) regarding the design and operation of digitizing circuitry, in general, are also gratefully acknowledged. The success of the fieldwork was strongly dependent upon the competent, willing, support of the US Navy squadron VP147 and US Navy Reserve squadrons VP65 and VP91/SAU0617. Special thanks are extended to Meredith H. Sessions of Scripps Institution of Oceanography for the use of his digitizing system on OPTOMA11P, and for accelerating the development of the ADDAS through numerous suggestions based on his AXBT flight experiences. Dr. John Bane of North Carolina State University also provided valuable advice and critiques.

This research was sponsored by the ONR Physical Oceanography Program.

APPENDIX A

NAVIGATION AND POSITION ACCURACY

Accurate geographic location of the AXBT deployments is imperative for the correct interpretation of the acquired data. To meet this requirement, (at least) four navigational systems are available on (most of) the P3 aircraft used in the OPTOMA Program. These systems are: 1) the LITON-72 Inertial Navigation System (INS), 2) Tactical Air Navigation (TACAN), 3) Long-Range Navigation (LORAN), and 4) Radio Detection and Ranging (RADAR). The P3-A aircraft, used occasionally in the OPTOMA program, does not have an INS unless one is brought onboard for a specific mission. The P3-'B Mod', used most often in the OPTOMA program, has an OMEGA navigational system in addition to the above four systems. Except for the inertial navigation system, all of the above systems are radio navigation aids which determine position by receiving and processing radio wave transmissions.

The TACAN system, developed for the military, operates in the Ultra-High Frequency (UHF) band and obtains continuous indications of distance and bearing from surface transmitters located within 300 nm, or line-of-sight distance from the aircraft (whichever is shorter). Distance is computed from the round-trip travel time of radio pulse signals sent from the surface station. The accuracy of this system is O(1) km, or 3% of the distance from the beacon (whichever is greater). In OPTOMA's NOCAL domain (centered 150 km from shore) the error in range will be at least 4.5 km. Bearing from the aircraft to the station is provided by the station which transmits a reference signal and a variable bearing signal. The signals are received at the aircraft, phase-measured, and converted into an azimuth bearing in degrees, with (ideal) 0.5 deg accuracy (or 1.3 km at 150 km). An indication of the position accuracy for each flight can be obtained by checking the TACAN ground position at a known location on the airstrip, before and after each mission.

The LORAN-C system operates in the 100 to 115 kHz frequency band and determines position by measuring the difference in time of reception of synchronized pulse signals from two or more land-based transmitters. Accuracy of geographic position can vary between 0.2 km to 5.0 km, depending upon the aircraft position with respect to the surface stations. In addition to the onboard LORAN, the ADDAS has a LORAN-C unit with similar accuracies, but more automatic operation.

On the OPTOMA flights, RADAR is used at the inshore stations to measure range and bearing with respect to known coastal features. The range is determined by measuring the round-trip travel time required for the radio wave to reach the object and return. The direction is determined by the position of the rotating antenna when the reflected portion of the wave is received. Accuracy of the range measurement is claimed to be O(1) km; accuracy of the bearing measurement is approximately one-half of the scanning beamwidth.

OMEGA is a global network of eight transmitting stations. These stations transmit in the Very Low Frequency (VLF) band so that the signals are receivable to ranges of thousands of miles. Each station transmits bursts of five different frequencies (in the 10.2 to 13.6 kHz range) multiplexed together so that any frequency is transmitted by only one station at a time. With eight stations transmitting at an approximate 1.0 sec interval and a 0.2 sec silent interval between each, the entire sequence is repeated every 10 sec. The airborne receiver synchronizes to the OMEGA broadcast pattern and measures the phase relationship to each available station from the receiver location. This phase measurement is then provided to a central processor where a circular distance to each station is computed. These distances are combined with a current aircraft dead reckoning position to compute the OMEGA position. Accuracy of the OMEGA system is consistently +/- 3.7 km, depending upon the level of sophistication of the aircraft receiver/processor and variations in the OMEGA signal due to geophysical effects, e.g, solar activity (diurnal and intermittent) and polar cap absorption.

The INS is the only navigation aid which is independent of land-based stations: the geographic position of the aircraft is determined via measurement of the local gravity vertical, which has a unique value at each point on the globe. The position, attitude and heading of the aircraft are computed using data from a two-axis accelerometer and a pair of two-axis gyroscopes, which provide a locally level frame of reference for the accelerometer. The accuracy of position, typically 1.8 km, degrades over the duration of a flight due to drift in the gyroscopes. There is also a known 84.4 minute oscillatory movement (the Schuler oscillation) associated with the gyroscopes. This periodic motion contributes a position error which increases with time and is manifested as an increase in drift rate. The INS used on the OPTOMA flights internally corrects for the Schuler oscillation and also outputs an estimate of the overall drift rate at the end of each mission.

As a result of the time-dependence of the INS drift error, positions will be more accurate in the first few hours of a flight. If the drift rate is considered to have a linear temporal dependence, then each station position can be corrected by an amount proportional to the elapsed time between takeoff and each deployment. However, to be more precise and to allow for any nonlinearity in the error, it is best to take the following precautions with the INS: 1) 'align' the INS at the beginning and end of each flight at a known location on the airstrip, and 2) monitor the drift rate at regular intervals during the flight, and correct for it in real-time, or record the value for post-flight correction.

On each flight the navigators intercompare the position readings from all of the various aids available to arrive at the best estimate for each station position. These estimates are based on 1) the frequency of occurrence of a particular reading within a set of readings from all the navigation aids, 2) past experience on how errors in the instruments occur, and are manifested in the readings, and 3) the operating environment on a particular day, e.g, rain and clouds scatter and reflect the RADAR transmissions, thus reducing its accuracy and usefulness as a navigation aid. It is likely that the subjectivity introduced by an experienced navigator will improve the the accuracy of the position estimate, not reduce it. By considering the readings from all of the instruments and by performing careful navigation checks throughout the flight it is estimated that the positions recorded are within +/- 3.7km (2 nm) of the true geographic location.

APPENDIX B

The points of origin of the OA maps correspond in latitude and longitude to the bottom left-hand corner of a box which just encloses the data points.

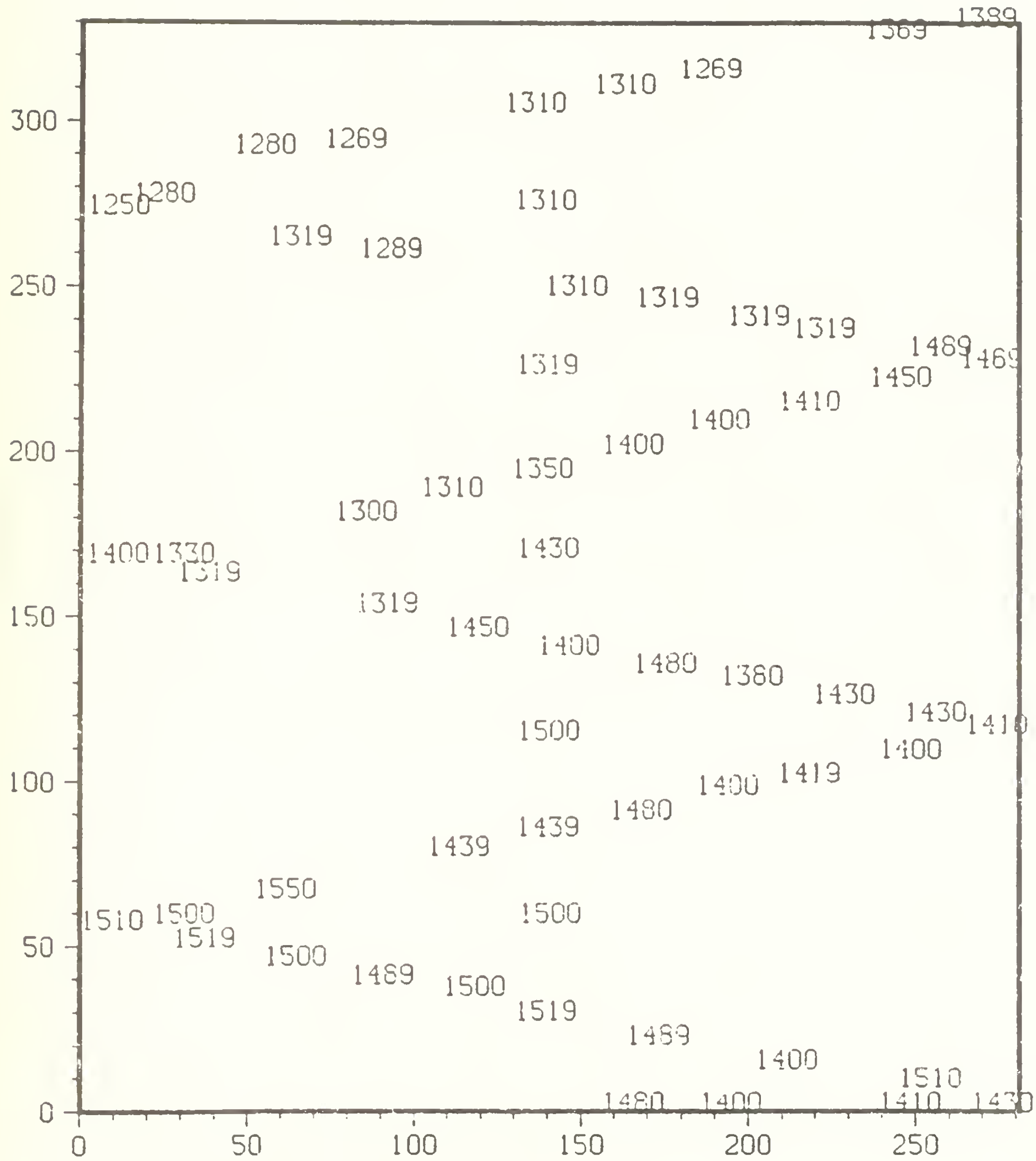


Figure B-1: Respective positions of AXBTs to OA grid (OPTOMA3). (Sea surface temperatures scaled by 100).

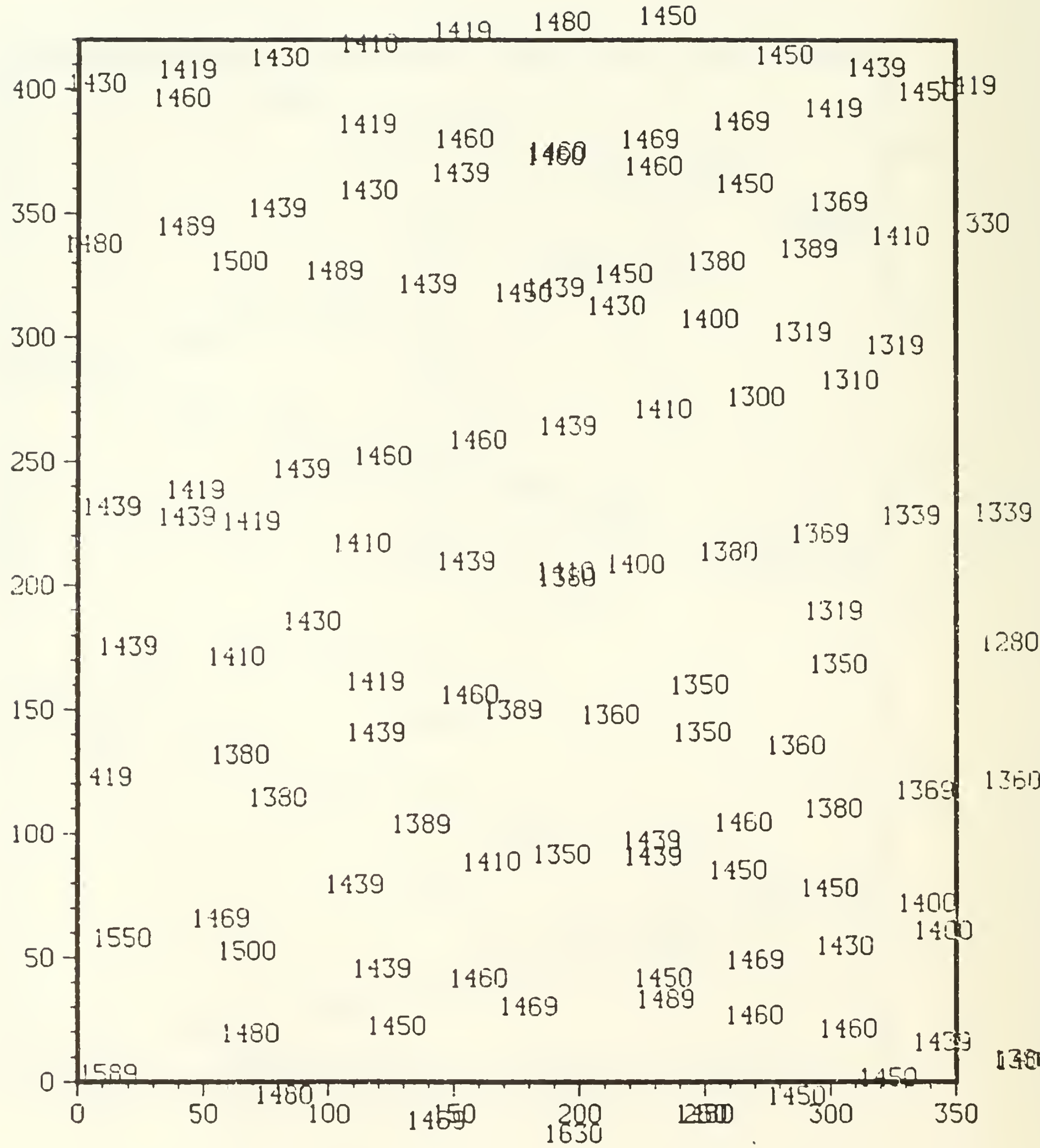


Figure B-2: Respective positions of AXBTs to imposed OA grid (OPTOMA8). (Sea surface temperature scaled by 100).

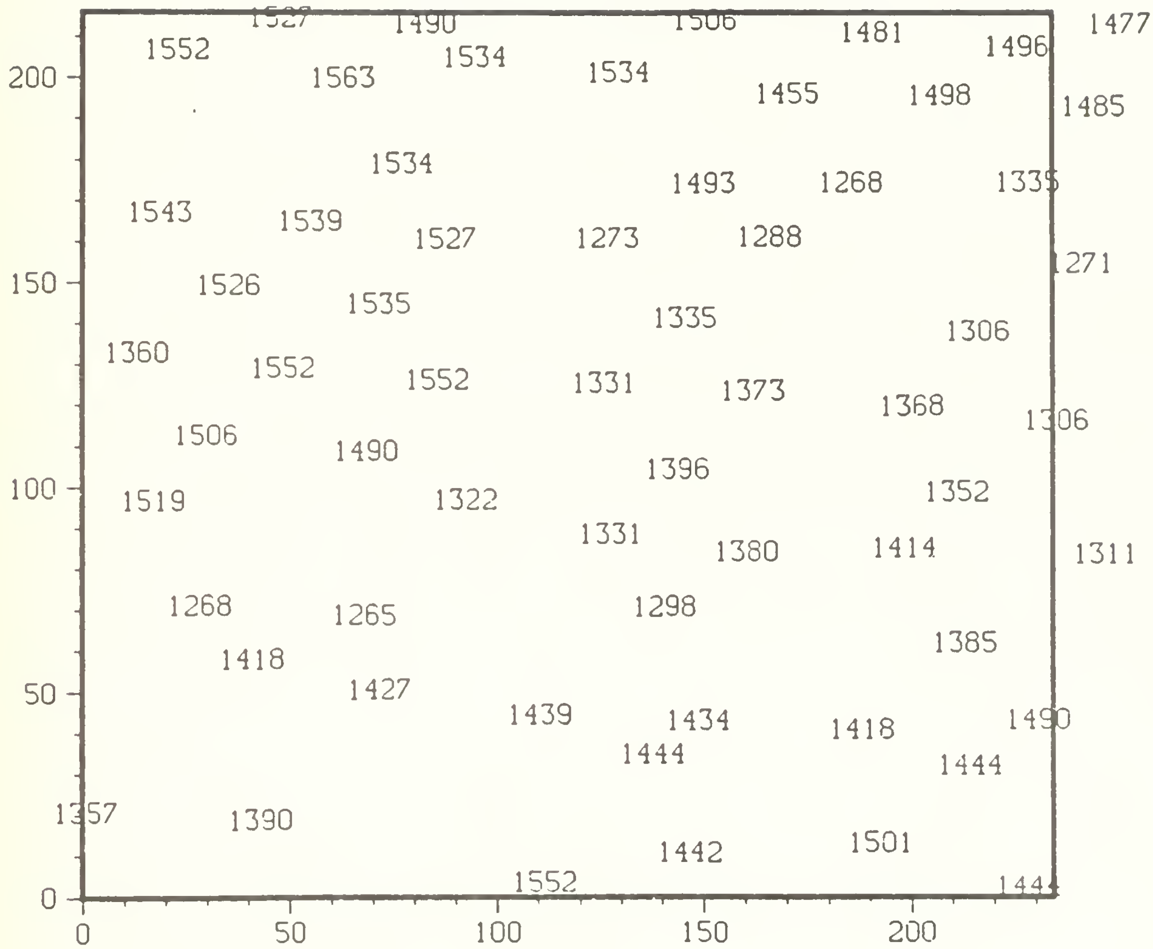


Figure B-3: Respective positions of AXBTs to imposed OA grid (OPTOMA11P). (Sea surface temperature scaled by 100).

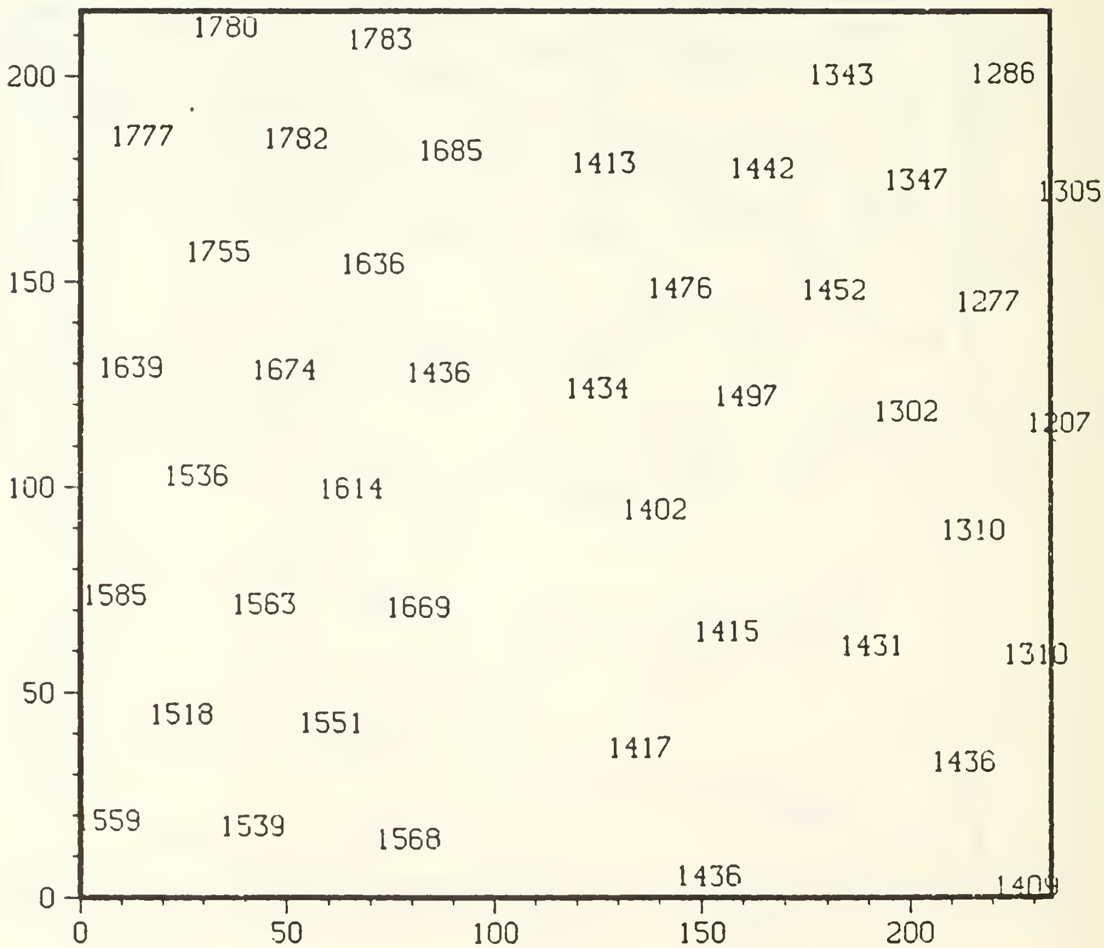


Figure B-4: Respective positions of AXBTs to imposed OA grid (OPTOMA13P).(Sea surface temperature scaled by 100).

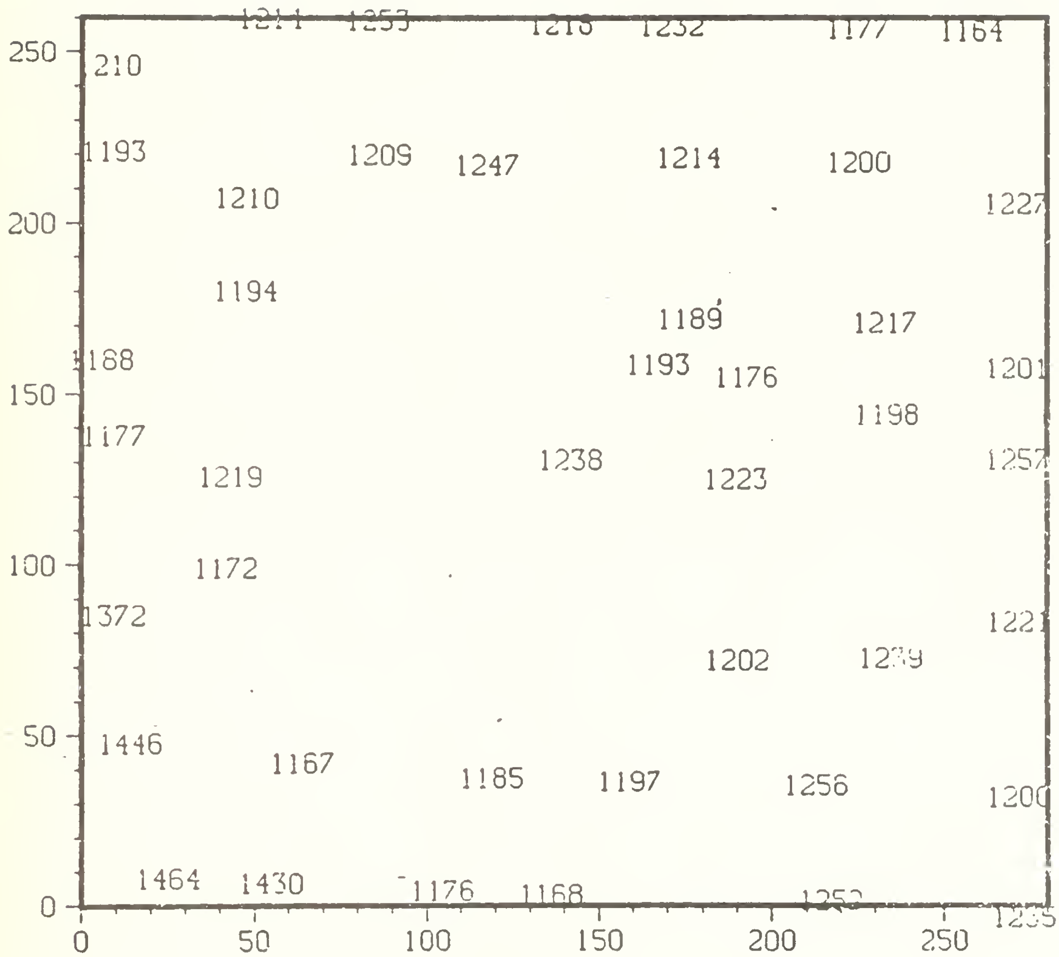


Figure B-5: Respective positions of AXBTs to imposed OA grid (OPTOMA15P). (Sea surface temperature scaled by 100).

APPENDIX C

"AXBT" PROGRAM INSTRUCTIONS AND PROGRAM LISTING

The AXBT data acquisition program "AXBT" is a streamlined version of the shipboard data acquisition program, combined with portions of the Sippican MK9 software which were modified for use on an HP9816 (a BASIC program listing follows the instructions section). The original shipboard version of the program was written for an HP9845 microprocessor which had a four byte real variable type. To conform to an IEEE standard, the HP9816, used in the ADDAS, now has an eight byte real variable type. Since the four byte (six digit precision) is adequate for the OPTOMA project, the eight byte variable of the HP9816 is used only within the AXBT program; on output the variables are shortened to four byte real variables, scaled, and written to disk as two byte integer variables. This output format is consistent with the shipboard program and it eliminates the need for doubled storage space. With the standard format (described below), all of the existing shorebased data editing and processing software can accept AXBT data.

Each data disk is formatted with eight files, each of which consists of 360, 18 byte records. The AXBT files contain 18 profiles of 20 records each; the first record of each profile contains header information as shown in Table C-1. At present the header information, except for the time and date from the internal clock, are entered manually for each AXBT deployment. The remaining 19 records of each profile contain a total of 684 two byte integer temperature values. Because the depth of each point is a computed variable, it is not stored on disk. After the flight the data are transferred from disk to the mainframe computer at NPS, at which time the depth profiles are computed and stored with the corresponding temperature in mass storage data sets.

ARRAY MEMBER	CONTENTS
(1)	= Hour + Second/100
(2)	= Latitude (degrees + minutes/100)
(3)	= Longitude - 100 (degrees + minutes/100)
* (4)	= Heading (decimal degrees) - 2.5 deg
(5)	= Wind Direction (degrees, 0-540 relative to ships bow)
(6)	= Wind Speed (meters/sec)
* (7)	= Dewpoint (degrees C)
(8)	= Air temperature (degrees C)
* (9)	= 2m Sea Surface Temperature (degrees C)
* (10)	= 2m Salinity (ppt)
* (11)	= Boom Sea Surface Temperature (degrees C)
(12)	= Station number
* (13)	= Ship water velocity (meters/sec)
* (14)	= Barometric pressure
# (15)	= Dynamic height at 10 meters
(16)	= Spare
(17)	= Number of points if CTD
	= XBT type is XBT (.6=T-7, 1=T-4, 2=300m AXBT, 4=750m AXBT
(18)	= Month + day/100 + Year*100

* Only on DAS ships

Only stored after hydrographic program is run.

Note: If radiometers are installed, the output voltages are packed and stored in 15 and 16.

Table C - 1: Contents of eighteen variable AXBT header array.

In the program "AXBT" there are three subprograms which perform the eight byte to four byte real variable conversions. The first, "Shinit" (Short Initialize), called at the beginning of the program, generates a look-up table to convert single byte Binary Coded Digits (BCD, the internal HP format) to their equivalent decimal values. The equivalence table is then stored as three arrays: two for the eight to four byte conversions (CON1, CON2); one for the four to eight byte conversions: Comb). These arrays reduce bit manipulations in the subprograms "Shrt" and "Ushrt" (described below), since subsequent conversions can be performed via a simple access by address of the equivalence table array. The second subprogram, "Shrt" (Short), called by the data saving subprogram "Save", is used for writing the output files to disk. In this routine the eight byte variables are converted into their four byte BCD equivalents. Upon return to "Save" the four byte real variables are scaled and packed into a two byte integer array, then written to disk. Finally, the third subprogram "Ushrt" (Unshort), called from the subprogram "Plotstd", is used to convert the stored four byte variables to their eight byte equivalents for use in the plotting routine "Plot".

The first actions taken after loading and running the program are the assignment of values to program constants and initialization of the running date and time display (Subprogram "Showtime"). The running display will continue until the special function key, 'k0', the "Menu" key, is pressed. The option menu is then displayed from which the operator may choose to (1) plot a previously stored AXBT, (2) change the date and time on the internal clock, (3) catalog a data disk to view its contents, or (4) prepare the system to receive AXBT data. The following sections outline the subprograms called by each option. Explicit instructions for the use of each option (CRT prompts and operator responses) follow each section.

Option '1': PLOT AXBT

Selection of this option branches the program to subprogram "Plotstd". Through a series of prompts, "Plotstd" establishes which AXBT is to be plotted from disk, reads and converts the header information from the particular file, and continues to the subprogram "Plot". In "Plot" the temperature-depth graph is prepared (2 to 16 deg C on the abscissa; 0 to 500 m (800 m for deep AXBTs) on ordinate), the data are read via subprogram "Pxbt" and the profile is drawn. As the profile is drawn, the temperature and depth values are written to the screen for operator information. Station number, time, date, latitude and longitude are written to the screen. Upon completion of the profile, a hard copy of the plot from the screen may be generated.

Option '1' Prompts and Responses

```
CRT:   Today's Menu
       1. PLOT AXBT
       2.
       3.
       4.
       Enter Number and push 'Continue'
OP:    (Enter) 1  push 'CONT'


CRT:   Plotting Routine for AXBTs
       Insert data disk and follow prompts
       Insert data disk and press continue
OP:    (Insert disk in right drive), push CONT


CRT:   (Displays disk contents) Filenumbers and Filetype
       Enter file number to plot
OP:    (Enter a number) 1 to 8, push CONT


CRT:   (If filenumber greater than 8) Enter filenumber
       to plot
OP:    (Try again)


CRT:(4 (If file does not contain AXBTs) This file does
```

not contain AXBT data. Do you want to plot another?
OP: (Enter either) Y or N, push CONT

CRT: (If filenumber and type are correct)
Enter AXBT entry number
OP: (Enter a number) 1 to 18, push CONT

CRT: (After completion of plot) Hard copy? (Y/N)
OP: (Enter either) Y or N, push CONT

Returns to 'Menu, after plot or 'N' response

Option '2': Change TIME

Selection of option '2' branches to the subprogram "Change Time". This option should be executed at the beginning of each flight to ensure that the correct date and time are stored on disk. This subprogram makes no additional branches and returns to the Menu upon completion.

Option '2' CRT Prompts and Operator Responses

CRT: Today's Menu
1.
2. Change TIME
3.
4.
Enter Number and push 'Continue'
OP: (Enter) 2 push 'CONT'

CRT: Time is _____ hours and _____ minutes
Enter the correct time in the form HHMM.SS
Enter correct time
OP: (For example) 1210.56

CRT: (If null entry; i.e., CONT) returns to 'Menu'
(If valid entry) Updating the clock

CRT: Enter date (YYMM.DD)
OP: (For example) 8407.18

CRT: The date and time have been corrected

Return to 'Menu'

Option '3': CATALOG Data Disk

Selection of option '3' branches the program to subprogram 'Cat (Catalog). In 'Cat' the directory of a given data disk is read and displayed on the screen for review.

Option '3' Prompts and Responses

CRT: Today's Menu
1.
2.
3. CATALOG Data Disk
4.
Enter Number and push 'Continue'
OP: (Enter) 3 push 'CONT'

CRT: Insert data disk then press continue
OP: (insert disk in right drive), press continue.

CRT: Just a second...
DISK CATALOG displayed
Last AXBT entry ___ in File __
Press Continue when you're done
OP: Press CONT to return to 'Menu'

Option '4': Mark9 AXBT

Selection of Option '4' branches the program to subprogram "Mark9". The first steps in "Mark9" assign the total number of measured points to be the standard 684 and set a special function key, 'k4', as an 'Abort' key which can be used to stop the profiling sequence and return to the 'Menu'.

The operator is then requested to input the type of AXBT (shallow or deep) and certain header information in response to prompts; the time and date from the internal clock are automatically stored in the header array.

Subprogram "Startd" is branched to next in which the data disk is prepared for input.

The microprocessor then sends a bit message to the MK9 unit to query the status of the AXBT digitizing circuit board. If a positive response is received (the board is present), then the microprocessor sends additional bits to the MK9 to prepare it for the AXBT launch. A negative response indicates that the AXBT board is not present, a message is printed and the entire program stops. If an input/output (I/O) error occurs between the HP9816 and the MK9, then a warning message is issued, the I/O interface is cleared, and the initial bit message is sent from the HP9816 again. The final preparatory steps before the launch set up the CRT screen for a real-time plot of the temperature-depth profile, via calls to subprograms "Realset" and "Plot".

The system is now ready for the AXBT launch and will trigger upon receiving the audio signal from the AXBT. The sampling interval of the MK9 is 0.1 seconds; therefore, a shallow AXBT which transmits for approximately 205 seconds will consist of a total of 2050 points and a deep AXBT which transmits for approximately 500 seconds will consist of 5000 points. Thus, to fit into the 684 point record, the incoming frequencies are averaged in groups of 3 and 7 points for shallow and deep AXBTs, respectively. The averaged frequency point is converted to temperature and a depth assigned to in the subprogram "At". The point is plotted on the screen and the temperature saved in an array. After the final point, the data are either stored or aborted and a hard-copy plot made according to the wishes of the operator. The data file and directory are closed and control is returned to the 'Menu' subprogram.

Option '4' Prompts and Responses

CRT:	Today's Menu 1. 2. 3. 4. Mark9 Enter Number and push 'Continue'
OP:	(Enter) 4 push 'CONT'
CRT:	Enter S for shallow or D for deep
OP:	(Enter either) S or D, push CONT
CRT:	Enter LATITUDE (dd.mmm)
OP:	(Example) 38.30
CRT:	Enter LONGITUDE (ddd.mmm)
OP:	(Example) 123.30
CRT:	Enter Station number
OP:	(Example) 10
CRT:	(Graph appears) Clear to Launch
OP:	(No response necessary)
CRT:	Enter S to store data or A to abort cast
OP:	(Enter either) S or A, push CONT
CRT:	Enter P to plot
OP:	(Enter) P, push CONT (to plot) Push CONT to return to 'Menu', no plot.

"AXBT" PROGRAM LISTING

```
10    !   RE-STORE "AXBT"
20    !*******************************************
30    !*** Data Acquisition Program for AXBT ***
40    !*** to run on HP216 with basic 3.0     ***
50    !*** Paul Wittmann  May   3 , 1985      ***
60    !*******************************************
70    !
80      OPTION BASE 1
90      DIM Ot$[40],Co$[3],In buffer$[2]
100     INTEGER Out(18,2)
110     DIM Ts(2010),Dpt(2010)  ! temperature and depth
120     DIM Dir(200),Ad(18)     ! directory and header
130     INTEGER I,J,L,Iad(36),Datal,Datah,Data
140 Init:  !*** initialize variables  ******************
150     Bx=1.524                ! drop coeffiecent
160     Nps=684                 ! number of points
170     Deg$=CHR$(179)          ! Degrees symbol
180     L1$=CHR$(10)&CHR$(13)   ! line feed
190     L2$=L1$&L1$             ! double space
200     Pa$=CHR$(12)            ! new page
210     Co$="???"               ! data type
220     Yr=85                   ! year
230     Date=Yr*100+5.28        ! date
240     Hpib=7                  ! interface adress
250     Xbt=720                 ! MK9 adress
260     Msu$=":HP8290X,704,1"   ! 3 1/2" disk drive
270   ! Msu$=":INTERNAL"        ! 5 1/4" internal disk drive
280     Plot=706                ! plotter address
290     Prth=714                ! printer address
300     PRINTER IS CRT
310     GOSUB Shinit            !Set up Look-up Table
320 Show time: ************ Running time display **
330     Mo=INT(Date-8500)
340     Day=DROUND(FRACT(Date)*100,2)
350     GCLEAR
360     PRINT CHR$(12)
370     DISP "Press Menu KEY to get the menu..."
380     ON KEY 5 LABEL "Menu" GOTO Menu
390     ON KEY 0 LABEL "Menu" GOTO Menu
400     Spm=TIMEDATE MOD 86400 ! sec past midnight
410     Hour=INT(Spm/3600)
420     Min=INT((Spm MOD 3600)/60)
430     Sec=INT(Spm-3600*Hour-60*Min)
440     PRINT TABXY(3,15);
450     PRINT "Greenwich Mean Time -->  ";
460     PRINT DROUND(Hour,2);":";DROUND(Min,2);
470     PRINT "  ";DROUND(Sec,2)
480     PRINT "     "
```

```
490     PRINT "   Todays date -->  ";Mo;"/";Day;"/";Yr
500     WAIT 1
510     GOTO 390  ! Continue
520 !*********************
530 Menu:   !*************
540 !*********************
550    OFF KEY 0
560    OFF KEY 5
570     GCLEAR
580     PRINT Pa$
590     PRINT L1$,"    Today's MENU:",L2$
600     PRINT TAB(5),"1. PLOT AXBT  "
610     PRINT TAB(5),"2. Change TIME"
620     PRINT TAB(5),"3. CATALOG Data Disk "
630     PRINT TAB(5),"4. Mark9 AXBT"
640    PRINT L2$
650    DISP "Enter Number & Push 'CONTINUE'... ";
660    INPUT " ",Choice$
670    PRINT "Option #";Choice$
680    SELECT Choice$
690    CASE "1"        ! plotting routine
700      Rtp$="***"  ! real time plot flag
710      Justc=0     ! flag for data just collected
720      GOSUB Plotstd
730      ASSIGN @Fat TO *
740      GOTO Show time
750    CASE "2"        ! reset the clock
760      GOSUB Change time
770      GOTO Show time
780    CASE "3"        ! catalog disk
790      GOSUB Cat
800      GOTO Show time
810    CASE "4"        ! axbt data acquisition loop
820      Co$="XBT"
830      GOSUB Mark9
840    CASE ELSE
850      GOTO Show time
860    END SELECT
870  !****************************************
880 Plotstd:  !****************************
890  !************************************
900     PRINT Pa$,"Plotting routine for AXBTs"
910     PRINT "Insert data disk and follow prompts"
920     INPUT "Insert disk and press continue",Y$
930     GOSUB Cat
940     INPUT "Enter file number to plot ",X
950     Jb=X*20
960    IF X>8 THEN 940
970     ASSIGN @Dir TO "DIR"&Msu$
980     ENTER @Dir;Dir(*)
990     Y=Dir(Jb+5)
1000    IF (Y>0) AND (Y<4) THEN 1060
1010    PRINT "This file does not have";
1020    PRINT "AXBT data"
1030    INPUT "Do you want to plot another?",Y$
```

```
1040    IF Y$<>"Y" THEN RETURN
1050    GOTO 940
1060     ASSIGN @Fat TO "FAT"&VAL$(X)&Msu$
1070     INPUT "Enter AXBT entry number ",En
1080     En=En-1
1090      ENTER @Fat,1+En*20;Out(*)  ! read header
1100      GOSUB Ushrt
1130 !*******************************************
1140 Plot: !******** PLOTTING ******************
1150 !*******************************************
1160    PRINT Pa$
1170    Dmin=0   ! Default depths
1180    Dmax=500
1190    IF Ad(17)=4 THEN Dmax=800      ! for deep axbts
1200    Tmin=2       ! temp minimum
1210    Sp=16        ! temp span
1220    Crt$="Y"     ! print on crt
1230      GINIT      ! initialize graphics
1240      GRAPHICS ON
1250   Tmax=Tmin+Sp
1260   Tfact=Sp/100
1270   Dfact=(Dmax-Dmin)/100
1280    DEG
1290    VIEWPORT 0,70,5,95
1300    CSIZE 2.5
1310   Xmn=Tmin-8*Tfact      ! scaling
1320   Xmx=Tmax+2*Tfact      ! factors
1330   Ymx=Dmin-5*Dfact      ! for
1340   Ymn=Dmax+10*Dfact     ! plot
1350   WINDOW Xmn,Xmx,Ymn,Ymx
1360   Ntic=8
1370   PEN 1
1380   CLIP Tmin,Tmax,Dmax,Dmin
1390   AXES Sp/2/Ntic,(Dmax-Dmin)/10,Tmin,Dmin,2,2
1400   CLIP OFF
1410   GOSUB Dlab    ! Label Depth axis
1420   GOSUB Tlab    ! Label Temperature axis
1430   IF Rtp$="T" THEN RETURN
1440   PEN 0
1450   GOSUB Pxbt    ! read axbt data
1460   PEN 1
1490   FOR I=1 TO Nps
1500       IF Dpt(I)<Dmin OR Dpt(I)>Dmax THEN 1520
1510       PLOT Ts(I),Dpt(I),1
1520   NEXT I
1530   PENUP
1538   IF Ad(18)<100 THEN Ad(18)=Ad(18)+Yr*100
1539   Gyr=INT(Ad(18)/100)
1540   Dat=Ad(18)-100*Gyr
1541   Mo=INT(Dat)
1542   Day=INT(100*FRACT(Dat))+1
1543   Year=INT(Ad(18)/100)
1555     PRINT TABXY(15,25);"Station:";Ad(12);" GMT:";Ad(1);" Date:";Mo;"/";Day;
1557     PRINT TAB(15);" Lat:";Ad(2);" Long:";Ad(3)+100
```

```
1558   Y$=" "
1559     PRINT TAB(15);"Hard Copy?(Y/N)"
1560     INPUT Y$
1561     IF Y$<>"Y" THEN 1570
1562     ON TIMEOUT Hpib,1 GOTO 1568
1563     DUMP DEVICE IS Prth
1564     DUMP GRAPHICS
1565     PRINTER IS Prth
1566     PRINT "Station:";Ad(12);" GMT:";Ad(1);" Date:";Mo;"-";Day;"-";Yr
1567     PRINT " Lat:";Ad(2);" Long:";Ad(3)+100
1568     PRINTER IS 1
1569     OFF TIMCOUT Hpib
1570     GCLEAR
1571   ASSIGN @Fat TO *
1572 RETURN
1573 !*****************************************************
1574 Pxbt:  !**** read data from disk *******************
1575 !*****************************************************
1576    L=0             ! counter
1577    Bx=1.5240       ! drop coeffiecent
1578   Tstep=.3                     ! time increment for shallow
1579   IF Ad(17)=4 THEN Tstep=.7  ! time increment for deep
1580   FOR I=2 TO 20
1581      ENTER @Fat,I+En*20;Iad(*)
1582         FOR J=1 TO 36
1583          L=L+1
1584          Time=Tstep*L
1585          Ts(L)=Iad(J)/100
1586          Dpt(L)=Bx*Time       ! depth equation
1587         NEXT J
1588   NEXT I
1589   RETURN
1590 !*******************************************
1591 Dlab: !***** Label vertical "Z"-axis *******
1592 !*******************************************
1593 LDIR 90
1594 LORG 4
1595 FOR Dd=Dmin TO Dmax STEP (Dmax-Dmin)/5
1596 MOVE Tmin-.5*Tfact,Dd
1597 LABEL USING "K";Dd
1598 NEXT Dd
1599  MOVE Tmin-3.5*Tfact,Dmin+(Dmax-Dmin)/2
1600 Dt$="DEPTH (meters)"
1601 LABEL USING "K";Dt$
1602 PENUP
1603 RETURN
1604 !******************************************
1605 Tlab: !*** Label temperature axis *********
1606 !******************************************
1607   LDIR 0
1608   LORG 6
1609   FOR Tp=Tmin TO Tmax STEP (Tmax-Tmin)/Ntic
1610     MOVE Tp,Dmin-Dfact*2.5
1611     LABEL USING "K";Tp
```

```
1612   NEXT Tp
1613   Ot$="TEMPERATURE (Deg C)"
1614   MOVE Tmin+(Tmax-Tmin)/2,Omin-4.5*Ofact
1615   LABEL USING "K";Ot$
1616   PENUP
1617   RETURN
1618 !******************************************
1619 Change time:!******************************
1620 !******************************************
1621   PRINT Pa$
1622   PRINT "Time is ";Hour;" hours and ";Min;" minutes "
1623   PRINT L2$
1624   PRINT "Enter the correct time in the form : HHMM.SS "
1625   Time=-999
1626   INPUT "Enter correct time ",Time
1627   IF Time=-999 THEN RETURN
1628   DISP "Updating the clock "
1629   H=INT(Time/100)
1630   M=INT(Time-100*H)
1631   S=(Time INT(Time))*100
1632   New=3600*H+60*M+S
1633   SET TIME New
1634   INPUT "Enter date (YYMM.DD)",Date
1635   WAIT 1
1636   PRINT L1$,"The date and time have been corrected"
1637   WAIT 1
1638   RETURN
1639 !******************************************
1640 Cat: !***** Disk Catalog *************
1641 !****************************************
1642 ! NOTE: This routine loads Dir(I)
1643   IF Choice$<>"7" THEN GOTO 1654
1644   PRINT CHR$(12),TABXY(5,6);
1645   PRINT "***********************************"
1646   PRINT TABXY(13,8),"DISK CATALOG OPTION"
1647   PRINT TABXY(5,10);
1648   PRINT "***********************************"
1649   PRINT TABXY(0,15);"Follow prompts at the ";
1650   PRINT "bottom of the screen."
1651   DISP "INSERT Data Disk, then press ";
1652   DISP "'CONTINUE'."
1653   PAUSE
1654   DISP "Just a second..."
1655   PRINT CHR$(12),L2$,"    DISK CATALOGUE :"
1656   ASSIGN @Dir TO "DIR"&Msu$
1657   ENTER @Dir;Dir(*)
1658   PRINT
1659   FOR I=1 TO 8
1660        X=Dir(I*20+5)+1
1661        T$=VAL$(Dir(20*I)+1.E-10)
1662        PRINT TAB(5),"FILE ";I;"  "&Ot$(X),
1663        IF Dir(I*20)=0 THEN 1665
1664        PRINT T$[4,5]&"/"&T$[6,7]&"/"&T$[1,2]&"     "&VAL$(Dir(20*I+1));
1665        PRINT ""
```

```
1666   NEXT I
1667   Xf=Dir(3)
1668   Xe=Dir(4)
1669   IF Xf=0 THEN GOTO 1671
1670   PRINT L2$,"LAST XBT ENTRY = ";Xe;" IN FILE ";Xf
1671   ASSIGN @Dir TO *
1672   IF Choice$<>"3" THEN RETURN
1673   DISP "Press 'CONTINUE' when you're done."
1674   PAUSE
1675   RETURN
1676   !*********************************************
1677 Mark9:  !** data acquisition   ***************
1678   !*********************************************
1679   Npts=684
1680   ON KEY 4 LABEL "ABORT" GOTO 1760
1681   ON KEY 9 LABEL "CAST" GOTO 1760
1682    Id$="S"
1683    ASSIGN @Xbt TO Xbt;FORMAT OFF
1684   INPUT "Enter S for shallow or D for deep",Id$
1685   INPUT "ENTER LATITUDE (dd.mmm)",Ad(2)
1686   INPUT "ENTER LONGITUDE (ddd.mmm)",Long
1687   Ad(3)=Long-100
1688   INPUT "ENTER STATION NUMBER ",Ad(12)
1689   Spm=TIMEDATE MOD 86400
1690   Hr=INT(Spm/3600)
1691   Min=INT((Spm MOD 3600)/60)
1692   Ad(1)=Hr*100+Min  !TIME HHMM
1693   Ad(18)=Day        !DATE YYMM.DD
1694   Ad(17)=2                     ! identification for shallow
1695   IF Id$="D" THEN Ad(17)=4     ! identification for deep
1696       GOSUB Startd             ! initialize disk
1697  ! start I/O with MK9 Are the correct boards present?
1698      OUTPUT Xbt USING "#,B";85
1699      ENTER Xbt USING "#,B";Resp,Board 1,Board 2
1700      PRINT "BOARDS",Resp,Board 1,Board 2
1701       IF Resp=42 THEN 1707
1702       BEEP
1703       PRINT "WARNING!!! BAD EDIU RESPONSE"
1704       PRINT "SHALL ATTEMPT TO RESTART"
1705       WAIT 2
1706       GOTO 1698 ! OUTPUT 85
1707        IF Board 1=3 OR Board 2=3 THEN 1711  ! boards are present
1708        PRINT "WARNING!!! AXBT BOARD NOT PRESENT"
1709        BEEP
1710        STOP
1711     OUTPUT Xbt USING "#,B";1 ! boards OK
1712     IF Board 1=3 THEN Board mask=49
1713     IF Board 2=0 THEN Board mask=50
1714     OUTPUT Xbt USING "#,B";Board mask,51,21,1,25,15
1715     OUTPUT Xbt USING "#,B";0
1716     DISP TAB(15);"Clear to Launch"
1717     OUTPUT Xbt USING "#,B";1
1718     PRINT Pa$
1719     GOSUB Realset ! set up real time plot
1720 ! begin data acquisition loop
```

```
1721       Int=3                      ! averaging interval for shallow
1722       IF Id$="D" THEN Int=7      ! averaging interval for deep
1723       BEEP                       ! start taking data
1724     FOR J=1 TO Npts
1725         Data=0
1726       FOR I=1 TO Int
1727        ENTER Xbt USING "#,2A";In buffer$
1728         Datal=NUM(In buffer$[1])
1729         Datah=NUM(In buffer$[2])
1730         Data=Datah*256+Datal+Data
1731         Time=Time+.1             ! increment time
1732        NEXT I
1733        Data=Data/Int             ! average over int
1734           GOSUB At               ! convert freq to temp
1735          DRAW Temp,Depth         ! real time plot
1736         Ts(J)=Temp               ! assign to temp array
1737         DISP TAB(10);"Temp ";DROUND(Temp,4),"Depth ";DROUND(Depth,4)
1738     NEXT J
1739    DISP "Finish taking data"
1740     INPUT "Enter S to store data or A to abort cast",Y$
1741     IF Y$="A" THEN 1760
1742     GOSUB Save
1743     ON TIMEOUT Hpib,1 GOTO 1754
1744    INPUT "ENTER P FOR PLOT",Y$
1745    IF Y$<>"P" THEN 1752
1746    DUMP DEVICE IS Prth
1747    DUMP GRAPHICS
1748    PRINTER IS Prth
1749    PRINT "Station:";Ad(12);" GMT:";Ad(1);" Date:";Mo;"/";Day;"/";Yr
1750    PRINT "Latitude:";Ad(2);" Longitude:";Ad(3)+100
1751    PRINTER IS 1
1752    Rtp$="N"
1753    GOTO 1758
1754    DISP "PLOTTER NOT ON LINE !!!  "
1755    WAIT 1
1756    BEEP 500,1
1757    BEEP 250,2
1758     GCLEAR
1759     OFF TIMEOUT Hpib
1760     ASSIGN @Fat TO *      ! close file
1761     ASSIGN @Dir TO *      ! close directory
1762     OFF KEY 4
1763     OFF KEY 9
1764    RETURN                 ! to menu
1765 !*****************************************
1766 Startd: !** Prepares for Disk input    ****
1767 !*****************************************
1768     INPUT "Insert data disk and press continue",Y$
1769      ASSIGN @Dir TO "DIR"&Msu$
1770      ENTER @Dir;Dir(*)     ! read directory file
1771     PRINT Pa$
1772     PRINT "Last AXBT file = ";Dir(3);" out of 8"
1773     PRINT "Last AXBT entry = ";Dir(4);" out of 10"
1774     WAIT 2
```

```
1775   IF Dir(4)=0 THEN 1777
1776   GOTO 1779
1777   Dir(4)=0               ! reset axbt entry
1778   Dir(1)=Dir(1)+1        ! uses next file
1779   Dir(3)=Dir(1)          ! last axbt file used
1780   Dir(4)=Dir(4)+1        ! update axbt entry
1781   IF Dir(4)>18 THEN 1777
1782   IF Dir(3)<9 THEN 1787 ! last axbt file
1783   BEEP  ! if disk is full
1784   PRINT "THIS DISK IS FULL ***************"
1785   ASSIGN @Dir TO *
1786   GOTO Startd
1787  Fn=Dir(3)  ! file number
1788  Jb=Fn*20
1789  ASSIGN @Fat TO "FAT"&VAL$(Fn)&Msu$  ! open file
1790  RETURN
1791 !*******************************************
1792 Realset:    !  prepares for real time plot  ***
1793 !*******************************************
1794   Rtp$="T"    ! flag for real time plot
1795   GOSUB Plot  !  go to plotting routine
1796   PENUP
1797   MOVE Tmin,Dmin
1798   RETURN
1799 !************************************************
1800 At: !***** frequency to temperature conversion *****
1801 !************************************************
1802      Depth=Bx*Time      ! depth equation
1803      IF Data=0 THEN Data=1
1804      Temp=9000000/Data
1805  Temp1=-126.662+.21995*Temp-.000170596*Temp^2+7.70534E-8*Temp^3
1806  Temp=Temp1-1.79581E-11*Temp^4+1.73823E-15*Temp^5
1807       RETURN
1808 !*************************************************
1809 Save:   !** stores data in das format **************
1810 !*************************************************
1811       PRINT "Storing data"
1812       Ent=Dir(4)-1          !CURRENT XBT ENTERY - 1
1813       Dir(Jb)=Ad(18)/100   !DATE YY.MMDD
1814       Dir(Jb+1)=Ad(1)      !TIME HHMM.SS
1815       Dir(Jb+5)=1          ! 1=DATA TYPE FOR XBT
1816       Dir(Jb+8)=Dir(Dp+1) ! LAST XBT IN FILE
1817     FOR I=1 TO Npts
1818       IF Ts(I)<8 THEN 1820
1819     NEXT I
1820     Ad(4)=Dpt(I)         ! depth of 8C
1821     Ad(11)=Ts(5)          ! surface temp
1822       GOSUB Shrt
1823        OUTPUT @Fat,Ent*20+1;Out(*)
1824           FOR I=2 TO 20
1825            FOR J=1 TO 36
1826             Iad(J)=INT(Ts((I-2)*36+J)*100)
1827            NEXT J
1828             OUTPUT @Fat,Ent*20+I;Iad(*)
```

```
1829          NEXT I
1830    ASSIGN @Dir TO "DIR"&Msu$
1831    OUTPUT @Dir;Dir(*)
1832    PRINT L2$,"File number";Dir(3)
1833    PRINT "Entry number ";Dir(4),L1$
1834    BEEP 200,1
1835       RETURN
1861 !********************************************
1862 Shinit: !**********************************
1863 !********************************************
1864 !  CREATE LOOKUP TABLES FOR SHORT BCD FORMAT
1865 !
1866   DIM Cv$[20],Conb(256)
1867   INTEGER Con1(100),Con2(100)
1868   IF Intxx=1 THEN 1711
1869   FOR Ji=0 TO 99
1870     OUTPUT Cv$ USING "#,ZZ";Ji
1871     Con1(Ji+1)=SHIFT(SHIFT(VAL(Cv$[1,1]),-4)+VAL(Cv$[2,2]),-8)
1872     Con2(Ji+1)=SHIFT(VAL(Cv$[1,1]),-4)+VAL(Cv$[2,2])
1873    NEXT Ji
1874    FOR Ji=1 TO 100
1875      Conb(Con2(Ji)+1)=Ji-1
1876    NEXT Ji
1877    RETURN
1878 !********************************************
1879 Shrt: !************************************
1880 !********************************************
1881 !   EMULATE HP9845 SHORT BCD FORMAT AND
1882 !   OUTPUT INTO INTEGER ARRAY Out
1883 !
1884    FOR Ji=1 TO 18
1885      OUTPUT Cv$ USING "#,S.DDDDDDE";Ad(Ji)
1886      Siqq=0
1887      Esiq=0
1888      IF Cv$[10,10]=" " THEN Esiq=-32768
1889      IF Cv$[1,1]="-" THEN Siqq=256
1890      IF Esiq<`0 THEN 1893
1891      Out(Ji,1)=SHIFT((VAL(Cv$[11,12])-1),-9)+Esiq+Siqq+Con2(1+VAL(Cv$[3,4])
1892      GOTO 1894
1893      Out(Ji,1)=SHIFT(63-(VAL(Cv$[11,12])),-9)+Esiq+Siqq+Con2(1+VAL(Cv$[3,4]
1894      Out(Ji,2)=Con1(VAL(Cv$[5,6])+1)+Con2(VAL(Cv$[7,8])+1)
1895      NEXT Ji
1896    RETURN
1897  ******************************************
1898 Ushrt:  !*********************************
1899  !******************************************
1900  !   DECODE HP9845 SHORT BCD NUMBERS READ
1901  !   READ FROM INTEGER ARRAY Out(18,2) AND
1902  !   LOAD INTO Ad(18)
1903  !
1904    FOR Ji=1 TO 18
1905       Exsgn=BIT(Out(Ji,1),15)
1906       IF Exsgn=1 THEN Expp=10^(-63+BINAND(SHIFT(Out(Ji,1),9),63))
1907       IF Exsgn=0 THEN Expp=10^(BINAND(SHIFT(Out(Ji,1),9),63)+1)
1908       Ad(Ji)=Conb(SHIFT(Out(Ji,2),8)+1)*.0001+Conb(BINAND(Out(Ji,2),255)+1
1909       Ad(Ji)=(1-2*BIT(Out(Ji,1),8))*Expp*(Conb(BINAND(Out(Ji,1),255)+1)*.0
1910     NEXT Ji
1911     RETURN
1912        END
```

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NOAA
Bldg. 3
7600 Sand Point Way, NE
Seattle, WA 98115

Mr. James R. Holbrook 1

26. Defense Technical Information Center 2
Cameron Station
Alexandria, VA 22314

27. Dudley Knox Library 2
Code 0142
Naval Postgraduate School
Monterey, CA 93943

28. COMRESPATWNGPAC
Moffett NAS
Moffett Field, CA 94035

LCDR Clark Heath 1
LCDR Gary Powell 1
LT Mark Johnson 1

29. COMPATWNG TEN
Moffett NAS
Moffett Field, CA 94035

CDR Wayne Jennings 1
LCDR Michael Wooster 1

30. COMASWNGPAC
Code 30A
North Island NAS
San Diego, CA 92135

Mr. Richard Tuck 1

31. NAVOCEANO
Tactical Analysis Division
Fleet Applications Department
NSTL Station, MS 39529

Mr. Allen Lewando 1

32. University of North Carolina
Curriculum in Marine Sciences
Chapel Hill, NC 27514

Dr. John M. Bane 1

33. NORDA - ONR Detachment
Code 422
NSTL Station
Bay St. Louis, MS 39520

CDR Robert Willems 1

34. NORDA
Instrumentation Branch
Code 252
NSTL Station
Bay St. Louis, MS 39520

C. Randy Holland 1
Ronald T. Miles 1