COMPARISON OF FLEET NUMERICAL WEATHER CENTRAL
ACOUSTIC PREDICTION SYSTEM WITH THE
INTEGRATED CARRIER ACOUSTIC PREDICTION SYSTEM
(ICAPS)

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NAVAL POSTGRADUATE SCHOOL

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THESIS

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Weather Central Acoustic Forecast
System and the Integrated Carrier
Acoustic Prediction System (ICAPS)

by

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ABSTRACT

The Naval Oceanographic Office developed the Integrated Carrier Acoustic Prediction System (ICAPS) in order to perform on-scene acoustic forecasts for the Fleet. To evaluate the system, bathythermographic information was obtained for points in the North Atlantic during the naval exercise "SEACONEX." Fleet Numerical Weather Central (FNWC) provided climatological and synoptic temperature profiles along with related acoustical forecasts for the points under study. Similarly, ICAPS supplied a combined climatological and synoptic temperature profile and related acoustic forecasts for each of the points. Comparisons of the two systems were made against an actual mean temperature profile and the acoustic forecast that it generated. It appears that the climatological acoustic forecasts were not reliable tactically. Yet, the synoptic forecasts by FNWC did yield reliable low frequency acoustic forecasts within the limits of computer roundoff error. ICAPS capability for only a single temperature profile input proved to yield reliable acoustic forecasts, and should be used as the real-time acoustic forecast system for the Fleet.

TABLE OF CONTENTS

I.	INTRODUCTION - - - - -	8
A.	OBJECTIVES - - - - -	8
B.	ACOUSTIC FORECASTING MODELS- - - - -	9
1.	Ship, Helicopter Acoustic Range Prediction System (SHARPS II)- - - - -	9
2.	Acoustic Sensor Range Prediction (ASRAP III)- - - - -	11
C.	INTEGRATED CARRIER ACOUSTIC PREDICTION SYSTEM (ICAPS) - - - - -	12
D.	TEMPERATURE PROFILE DERIVATION - - - - -	12
1.	Fleet Numerical Weather Central- - - - -	12
a.	Sea Surface Temperature Analysis - - - - -	13
b.	Mixed Layer Depth Analysis - - - - -	13
c.	Sub-Surface Temperature Analysis - - - - -	13
d.	FNWC Climatology - - - - -	13
2.	ICAPS Temperature Profile- - - - -	14
a.	ICAPS Climatology- - - - -	14
II.	COMPARISON OF TEMPERATURE AND ACOUSTIC PROFILES- - - - -	15
A.	BASIS FOR COMPARISONS- - - - -	15
1.	Limitations on Data Used in This Study - - - - -	17
B.	CLIMATOLOGY COMPARISON - - - - -	17
1.	Temperature Profile- - - - -	17
2.	Acoustic Predictions - - - - -	34
3.	Discussion of Results- - - - -	38

C.	SYNOPTIC COMPARISON - - - - -	42
1.	FNWC Synoptic Temperature Profile - - - - -	42
2.	FNWC Acoustic Forecast- - - - -	50
III.	ICAPS I/O ANALYSIS- - - - -	53
A.	TEMPERATURE INPUT - - - - -	53
B.	ICAPS ACOUSTIC OUTPUT - - - - -	55
IV.	CONCLUSIONS - - - - -	61
A.	CLIMATOLOGY - - - - -	61
B.	SYNOPTIC- - - - -	61
C.	OPERATIONAL CONSIDERATIONS- - - - -	62
V.	RECOMMENDATIONS - - - - -	64
A.	STANDARD DEVIATION FIELDS - - - - -	64
B.	TRAINING OF ICAPS OPERATORS - - - - -	64
C.	ALTERATIONS TO ICAPS SYSTEM - - - - -	64
D.	FNWC PROGRAM ALTERATIONS- - - - -	65
APPENDIX A:	FNWC SEA SURFACE TEMPERATURE ANALYSIS- - - - -	67
APPENDIX B:	FNWC MIXED LAYER DEPTH ANALYSIS- - - - -	72
APPENDIX C:	FNWC SUB-SURFACE TEMPERATURE ANALYSIS- - - - -	76
REFERENCES-	- - - - -	77
INITIAL DISTRIBUTION LIST	- - - - -	78
DD FORM 1473-	- - - - -	80

LIST OF TABLES

I.	Lewit's (1972) standard deviation (SD) tables for positions of study - - - - -	19
II.	Comparison of FNCL and NAVOCL with mean temperature profiles for high SD positions - - - - -	22
III.	Comparison of FNCL and NAVOCL with mean temperature profiles for low SD positions- - - - -	28
IV.	Acoustic range analysis for high SD and low SD positions- - - - -	36
V.	Differences between FNWC mean and actual mean temperature profiles - - - - -	43
VI.	Range compatibility between acoustic forecasts based on a mean synoptic temperature profile and the FNWC mean temperature profile- - - - -	51
VII.	Variances for all positions of study - - - - -	54
VIII.	Range compatibility between single BT input and mean temperature profile acoustic forecasts- - - - -	59

LIST OF ILLUSTRATIONS

1. Location of bathythermographic data collection points - - - - -	16
2. Graph of normalized standard deviation for data collection points - - - - -	20
3. Normalized difference versus depth for positions of high standard deviation - - - - -	23-26
4. Normalized difference versus depth for positions of low standard deviation- - - - -	29-33
5. FOM determination of range - - - - -	37
6. Isotherms for position B - - - - -	39
7. Differences between the FNWC mean temperature profile and the actual mean temperature- - - - -	45-49
8. Graph of temperature profiles and the mean temperature profile- - - - -	56-58
9. Flow diagram for SST analysis- - - - -	68
10. Grid diagram for SST analysis- - - - -	69
11. Basic flow chart for sub-surface temperature analysis - - - - -	74-75

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I. INTRODUCTION

A. OBJECTIVES

The primary objective of this study is to compare the ocean thermal structure analyses and acoustical products of Fleet Numerical Weather Central (FNWC) with the Integrated Acoustic Prediction System (ICAPS) thermal structure inputs and acoustic forecasts. This comparison is intended to evaluate the overall credibility of both systems. The data used in this study were collected aboard the USS GUAM (LPH-9) during the naval exercise "SEACONEX" held in the North Atlantic Ocean in June 1973.

In order to accomplish this objective (basic plan including discussion of FNWC models, etc.) this paper presents a brief discussion of the merits of the climatology used by FNWC and the new interim climatology developed by the Naval Oceanographic Office for the ICAPS system. Additionally the FNWC synoptic temperature profile and its related acoustic field are compared to those generated by using average mean bathythermograph (BT) profiles obtained at sea. The value of a single BT in the real ocean is discussed. In the case of a single BT profile obtained aboard ship, a theory concerning the errors associated with using such a profile is advanced.

A second objective of this study is to appraise the operational techniques required for ICAPS. By a detailed discussion of the strengths and weaknesses of ICAPS temporary profile inputs combined

with suggestions on how to capitalize on the strengths and compensate for the weaknesses, a pattern of operation will be projected. Planning and operating procedures for the use of ICAPS are proposed. Discussions are aimed at the procurement and processing of oceanographic data rather than the tactical utilization of such information. The goal of this portion of the study is to improve the effectiveness of the shipboard acoustical forecaster.

B. ACOUSTIC FORECASTING MODELS

The Fleet Numerical Weather Central (FNWC) in Monterey, California, currently produces and distributes to the fleet two primary acoustic forecasting products, the Ship, Helicopter Acoustic Range Prediction System (SHARPS II) and the Acoustic Sensor Range Prediction (ASRAP III) (Navweaservcom, 1971a,b).

1. Ship, Helicopter Acoustic Range Prediction System (SHARPS II)

The Ship, Helicopter Acoustic Prediction System (SHARPS) is a computerized sonar range prediction scheme. It is designed to take environmental analyses and convert them into acoustic range predictions. Inputs to the program include average equipment parameters, platform speed, sonar operating mode, sensor and target depth. Range predictions are based upon a single-ping, 50 percent probability of target detection by an unalerted sonar operator.

The key input to the SHARPS II program is the vertical temperature profile. This, along with the climatological salinity profile, is transformed by the use of Wilson's (1960) equation for sound speed into a sound velocity profile (SVP). In turn, the SVP is used to generate a raytrace pattern considering direct path,

purely refracted, and the surface and bottom reflected propagation paths. The change in sound intensity with range is computed considering losses due to spreading, scattering, reverberation, absorption, and surface and bottom reflections. Average performance characteristics are used for each sonar type, and an estimate of the sound intensity as a function of range is achieved. Considering that for active sonars a two-way travel distance (distance from source to target and return) is needed; the amount of propagation loss is double that of the one-way travel.

SHARPS II claims increased accuracy over previous models. This accuracy is attributed to (1) use of the modified Atlantic Meteorological and Oceanographic Study (AMOS) equations for surface channel, direct path, and sub-surface duct computations; (2) inclusion of the physics of the operational raytrace and propagation loss model techniques for bottom bounce and convergence zone computations; (3) inclusion of the basic reverberation technique used in the Navy Interim Surface Ship Sonar Prediction Model (NISSM) developed by Mobile Sonar Technology (MOST) Committee; and (4) increased input data to the model including a description of the SVP from the surface to the bottom, a detailed sonar system description for all equipments, and area scattering strengths for reverberation computations.

Each prediction is made for a predetermined acoustical area in which several assumptions are made: (1) water depth is constant; (2) SVP is horizontally constant; and (3) bottom composition and roughness are constant. Predictions are made on the basis of 12

hourly environmental temperature analyses by FNWC. The reliability and variability of that temperature input directly affects the reliability and variability of the acoustic forecast.

2. Acoustic Sensor Range Prediction (ASRAP III)

The ASRAP III program is directed toward the requirements of the airborne acoustic sensors, primarily the passive sonobuoys. Normally two distinct forecasts are available: a forecast of passive propagation loss at discrete frequencies, and a forecast for the active airborne sensors, primarily the active sonobuoys.

ASRAP III uses a sophisticated propagation loss model which employs an analytical solution to the wave equation to determine the acoustic intensity for various ray paths. The ocean is divided into acoustically homogeneous areas in which factors that affect sound propagation remain constant in the horizontal. In general, the intensity level at a receiver is a combination of sound arriving from the same four paths mentioned in the SHARPS discussion. Losses of energy by reflection from a boundary, spreading, and scattering are calculated for propagation within the surface duct and below it. Of course, with a passive system only one-way transmission from the source to receiver must be considered.

The SVP used by the ASRAP program is derived in the same manner as that used by SHARPS. Similarly, the reliability of the ASRAP acoustical forecast is a function of the reliability of the temperature profile.

C. INTEGRATED CARRIER ACOUSTIC PREDICTION SYSTEM (ICAPS)

The Naval Oceanographic Office (NAVOCEANO) and the Naval Undersea Center, San Diego (NUC), have developed an acoustic prediction system capable of providing on-scene forecasts. A mobile unit capable of rapid forecasts, yet small enough to be used aboard destroyers, submarines and VP aircraft, this system has added a new capability to acoustic prediction. The system, now called the Integrated Carrier Acoustic Prediction System (ICAPS), is composed of a Data General Corporation Nova 800 computer, a Pertec tape recorder, a Tektronix 4002A graphic computer terminal with CRT, and a Tektronix hard copy unit (Consultec, 1972).

In order to ensure that the ICAPS forecast is acoustically valid, the system has been programmed with the SHARPS II and ASRAP III models. This gives the unit the advantages of the sophisticated acoustic models used by FNWC. A significant difference does exist between this on-scene approach and that used by FNWC. FNWC uses available BT reports from the preceding 72 hours and depends heavily upon climatology, even in the near surface region. ICAPS uses recent BT profiles, or composites of them, in the near surface region. NAVOCEANO has developed a preliminary climatology for ICAPS which provides the thermal structure at depths greater than range of the BT.

D. TEMPERATURE PROFILE DERIVATION

1. Fleet Numerical Weather Central

FNWC computes the thermal structure in the upper 1200 feet in the Northern Hemisphere every 12 hours. This analysis is

composed of three parts: a sea surface temperature analysis, a mixed layer depth analysis, and a sub-surface temperature analysis.

a. Sea Surface Temperature Analysis

The present scheme used by FNWC for sea surface temperature (SST) analysis is the Fields by Information Blending (FIB) technique (Holl, et al, 1971). FIB performs numerical analysis of temperature fields by the assimilation and the blending of information from observations and climatological averages of sea surface temperatures. It combines information from three stages in time--current, near past and historical temperatures. Details of the analysis procedure are given in Appendix A.

b. Mixed Layer Depth Analysis

The mixed layer depth (MLD) is computed by the POTMLD program, which takes into account both climatological and synoptic information (Hesse, 1973). Details are given in Appendix B.

c. Sub-surface Temperature Analysis

The sub-surface analysis model as described in the new FNWC Computer Products Manual (Hesse, 1973) is constructed on the premise that the number of BT's available in any one day is small, much too small to make a truly synoptic analysis possible. Thus, it seeks to make use of the BT information that is available, but with a strong dependence upon climatology and the most recent SST analysis. Details are given in Appendix C.

d. FNWC Climatology

Stevens (FNWC, personal communication) indicated that FNWC developed its Atlantic climatology based upon National Oceanic

Data Center (NODC) station data, various atlases and from 500,000 - 1,000,000 mechanical BT observations. This data was weighted so that the effects of a small amount of data from any time period would not be treated with the same weight as a larger amount of data for another time period or area. This step was necessary to ensure that the resulting climatology profile would be representative of the entire time period to which it pertained, and would not be dominated by any limited portion of the data.

2. ICAPS Temperature Profile

Fox (NAVOCEANO, personal communication) stated that either a single BT observation or a hand-prepared composite may be used as an input. This is merged at 1200 feet by the computer with the ICAPS climatology. There are presently no capabilities for storage of BT reports for the previous 72 hours nor is there a function for the preparation of composite BT profiles in time or space. Also, no gross error check (GEC) is performed by the computer.

a. ICAPS Climatology

The Atlantic climatology used by ICAPS was developed by NAVOCEANO as an interim climatology until a more sophisticated model could be developed. Temperature data were taken from NODC files and the NAVOCEANO oceanographic atlas. All available information within each five degree square of ocean area was averaged at standard levels to obtain the climatological profile. An average MLD for the area was also included (Fox, personal communication).

II. COMPARISON OF TEMPERATURE AND ACOUSTIC PROFILES

A. BASIS FOR COMPARISONS

The purpose of this portion of the paper is to compare the temperature profiles used by FNWC with those used by the ICAPS program for the generation of their respective acoustical forecasts. As discussed in Chapter I, the temperature input to ICAPS normally consists of the latest available BT to a depth of 1200 feet. Below 1200 feet the BT trace is merged by the computer with the ICAPS climatology (Consultec, 1972). For the upper 1200 feet FNWC uses the available SST and BT reports, blending them in the horizontal with climatology and the analysis for the previous 12 hours. The analyzed temperature profile is then merged with the FNWC climatology below 1200 feet (Hesse, 1973). When BT reports are not available, both FNWC and the ICAPS program can generate acoustical forecasts using only their respective climatologies.

The data required to compare the FNWC and ICAPS temperature profiles includes on-scene BT reports, the FNWC analyzed thermal structure, and the FNWC and ICAPS climatologies. The at-sea data were collected on board USS GUAM (LPH-9) in the North Atlantic Ocean during June 1973. These profiles were obtained by the ships and helicopters participating in exercise "SEACONEX." The BT profiles were simultaneously used as inputs to the ICAPS program and sent to FNWC as inputs to their thermal structure analysis program. The data collection points are indicated in Figure 1. It should be noted

Figure 1. Location of bathythermographic data collection points.

that due to the nature of the exercise, considerably more data were collected at points B, C, and D than at the other points. While on board USS GUAM the ICAPS climatology profiles were also obtained. Additionally, during June the FNWC thermal structure analysis and climatological profiles were collected and held at FNWC. All acoustic forecasts were based upon the same salinity profile; therefore, that parameter does not enter this study as a variable.

1. Limitations on Data Used in This Study

Admittedly, because of the severe limitations of the study with regards to time (limited to June) and space (given points only), conclusions reached must be treated as applicable only as first approximations. Another constraint which was present during this exercise is that a transiting exercise limits the number of BT's that can be taken in an area. Thus any statistical products could be in error on the same order of magnitude as the expected variability in that area. Were all samples to be taken at a time and place experiencing a maximum in deviation and in the same sense, then a biased statistical base would be developed. Thus only definite trends in this study will be regarded as indicative. Extrapolations to other areas or time periods may not be valid.

B. CLIMATOLOGY COMPARISON

1. Temperature Profile

As mentioned in Appendix A, at FNWC temperature data are analyzed and merged at designated depths. Since most BT's obtained today are valid at least to a depth of 1200 feet, all comparisons

are limited to these levels. The basis for comparison is the simple average of all BT's taken at a position during a specific time period; this is termed the actual mean temperature profile. Thus, this comparison is restricted to comparing FNWC climatologies and ICAPS climatology for the upper 1200 feet. As differences between the climatologies and the actual mean will be studied, the appreciable differences will be assumed to occur only in this surface area.

Since this study deals with deviations from a mean temperature profile, it is advantageous to separate the geographical areas from which data were obtained into areas where the vertical temperature profiles exhibit relatively small or large standard deviations, respectively. This will permit an investigation of any relationship between expected standard deviation for an area and the thermal and acoustic reliability of forecasts for that area.

To properly separate the positions into regions of high or low standard deviation, tables of expected standard deviation constructed by FNWC (Lewit, 1972) are used. These tables cover two degree squares over all ocean areas. Table I lists the values for the positions used in this study.

Normalization of the standard deviation for each depth is accomplished by dividing the standard deviation at that depth by the maximum standard deviation of the column. These results are plotted in Figure 2 with those areas judged as having large standard deviations to the right and those with small standard deviations to the left. This judgment is based on the requirement that at 800 feet the curves should have a standard deviation less than 0.3 and at deeper depths, they remain below 0.3. With this criteria, artificially

Table 1. Lewit's (1972) standard deviation (SD) tables for positions of interest. Included under total is the number of observations that were used to calculate the standard deviation, given in degrees centigrade.

Position Depth	A		B		C		D		E	
	SD	Total	SD	Total	SD	Total	SD	Total	SD	Total
00	1.5	56	1.0	57	1.0	57	1.5	10	1.0	4
100	1.1	40	1.0	35	1.0	35	0.9	10	0.8	4
200	1.3	39	0.9	35	0.9	35	0.5	10	0.8	2
300	1.1	37	0.8	35	0.8	35	0.6	9	0.9	2
400	0.9	32	0.7	34	0.7	34	0.5	9	0.8	2
600	0.6	27	0.4	29	0.4	29	0.2	7	0.5	2
800	0.7	24	0.4	27	0.4	27	0.3	7	0.3	2
1200	0.8	11	1.2	23	1.2	23	0.0	4	0.0	1

Position Depth	F		G		H		I		J	
	SD	Total	SD	Total	SD	Total	SD	Total	SD	Total
00	1.0	4	0.6	2	0.7	3	0.5	3	2.2	7
100	0.8	4	0.5	2	1.1	3	0.0	1	1.3	7
200	0.8	2	0.0	1	1.4	3	0.0	1	1.3	6
300	0.9	2	0.0	1	1.2	3	0.0	1	1.3	6
400	0.8	2	0.0	1	0.6	3	0.0	1	1.7	6
600	0.5	2	0.0	1	0.3	3	0.0	1	2.2	5
800	0.3	2	0.0	1	0.1	3	0.0	1	2.8	4
1200	0.0	1	0.0	1	0.2	3	0.0	1	3.4	4

Figure 2. Graph of normalized standard deviation for data collection points. Values are obtained from Lewit's (1972) tables. Figure A is for areas having small standard deviation, figure B is for areas with large standard deviation. Standard deviation given in °C.

imposed by this investigator, points A, B, C and J are judged as having a large vertical temperature variability and while at points D, E, F, G, H and I, the temperature variability is expected to be low. As expected, points near strong currents, e.g., the Gulf Stream, show large variability while points in relatively calm waters e.g., the Sargasso Sea, show low variability.

Table II shows the comparison of the FNWC climatology (FNCL) and NAVOCEANO climatology (NAVOCL) with the actual mean temperature profile for the three areas A, B, and J. Differences between each climatology and the mean for each 12-hour forecasting period are given along with the normalized figures. Normalization is accomplished by dividing the difference at any level by the maximum difference of either column.

Normalization is computed to establish a percentage comparison between climatologies of FNWC and NAVOCEANO with respect to the mean temperature profile. Figures 3 a,b,c and d are graphs of the normalized differences with linear interpolation between points for positions B, A, and J. Were a climatology to agree perfectly with the mean, the curves would rest exactly on the zero ordinate. The relative size of the normalized difference at any level is a measure of the error associated with that climatology such that 1.0 is the maximum relative error. Thus an area between the curve and the 0.0 normalized difference line is an indication of the error present.

$$\frac{\text{AREA FNCL} - \text{AREA NAVOCL}}{\text{AREA FNCL}} = \text{PERCENT DECREASE IN ERROR} \quad (1)$$

Equation (1) is used to give a quantitative measure of the decrease in error associated with the FNCL.

INCLOSURE
ABOUT 1400 CH
5 3000

Table II. Comparison of FNCL and NAVOCL with mean temperature profiles. Differences are normalized. Number of observations upon which the mean is calculated is given in parenthesis. Mean profiles are given for indicated Zulu time periods.

Position A

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (4)	FNCL-MEAN		NAVOCL-MEAN	
				Absolute	Normal	Absolute	Normal
			0600	0600	0600	0600	0600
00	24.8	22.6	24.7	.2	.1	2.1	1.0
100	24.3	21.8	23.1	.8	.4	1.3	.6
200	20.7	20.6	21.7	1.0	.5	1.1	.6
300	19.7	19.9	20.7	1.0	.5	.8	.4
400	19.1	19.2	19.8	.7	.3	.6	.3
600	18.6	18.2	18.9	.3	.1	.7	.3
800	18.3	18.0	18.5	.2	.1	.5	.1
1200	17.8	17.5	17.6	.1	.0	.1	.1

Position J

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (2)	FNCL-MEAN		NAVOCL-MEAN	
				Absolute	Normal	Absolute	Normal
			1112	1112	1112	1112	1112
00	24.3	22.5	23.3	1.0	.5	.8	.4
100	24.3	21.7	22.3	2.0	1.0	.6	.3
200	20.5	19.9	19.8	.7	.4	.1	.1
300	19.4	18.8	18.9	.5	.2	.1	.1
400	18.9	18.8	18.8	.1	.1	.0	.0
600	18.4	18.0	18.0	.4	.2	.0	.0
800	18.0	17.7	17.7	.3	.2	.0	.0
1200	17.5	17.5	17.2	.3	.2	.3	.2

Position B

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (3)		FNCL-MEAN			NAVOCL-MEAN		
			(3)	(3)	Absolute		Normal	Absolute		Normal
					0800	0812	0800 0812	0800	0812	0800 12
00	24.2	22.5	25.1	25.1	.9	.9	.4 .4	2.6	2.6	1.0 1.0
100	24.0	22.5	23.0	23.6	1.0	.4	.4 .1	.5	1.1	.2 .4
200	20.5	20.0	21.3	21.6	.8	1.1	.3 .4	1.3	1.6	.5 .6
300	19.5	18.8	20.7	20.5	1.2	1.0	.5 .4	.9	1.7	.4 .7
400	18.9	18.5	20.2	20.0	1.3	1.1	.5 .4	1.7	1.5	.7 .6
600	18.6	18.0	19.5	19.2	.9	.6	.4 .2	1.5	1.2	.6 .5
800	18.6	17.8	18.9	18.5	.5	.1	.2 .0	1.1	.7	.4 .3
1200	17.9	17.5	18.3	17.5	.4	.4	.1 .2	.8	.0	.3 .0

Position B

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (3)		FNCL-MEAN			NAVOCL-MEAN		
			(3)	(2)	Absolute		Normal	Absolute		Normal
					0900	0912	0900 0912	0900	0912	0900 0912
00	24.2	22.5	25.0	25.0	.8	.8	.3 .3	2.5	2.5	1.0 .8
100	24.0	22.5	22.9	24.2	1.1	.2	.4 .1	.4	1.7	.2 .6
200	20.5	20.0	20.2	23.1	.2	2.6	.1 .9	.7	3.1	.3 1.0
300	19.5	18.8	20.5	22.0	1.0	.5	.4 .2	1.7	1.2	.7 .4
400	18.9	18.5	19.6	20.3	.7	.4	.3 .1	1.1	1.8	.4 .6
600	18.6	18.0	19.2	19.1	.6	.5	.2 .2	1.2	1.1	.5 .4
800	18.6	17.8	18.7	18.8	.3	.4	.1 .1	.9	1.0	.4 .3
1200	17.9	17.5	17.8	17.8	.1	.1	.0 .0	.3	.3	.1 .1

Figure 3A. A graph of the normalized difference between mean temperature profile and NAVOCL and FNCL for position B at 0800 local time.

Figure 3B. A graph of the normalized difference between mean temperature profile and NAVOCL and FNCL for position B at 0900 local time.

Figure 3C. A graph of the normalized difference between mean temperature profile and FNCL and NAVOCL for position A.

Figure 3D. A graph of the normalized difference between mean temperature profile and FNCL and NAVOCL for position J.

With this comparison basis, at position A (Figure 3c) FNCL yields a 14% smaller error than NAVOCL. Contrarily, for position J (Figure 3d), NAVOCL yields a 35% error reduction. For all four forecast periods for position B (Figure 3a,b) FNCL shows a substantial decrease in error compared to NAVOCL. Specifically, it yields a 29%, 52%, 51% and 60% decrease in error respectively.

For position J only two observations are available to obtain the mean temperature profile. For the other positions the means are based upon a greater number of observations. Thus for position J, that NAVOCL is closer to the mean profile is probably not significant. For all remaining forecasts, FNCL had substantially less error than NAVOCL. It is concluded from this trend that in areas of expected large standard deviation, FNCL is a better approximation to the mean temperature profile.

Analysis of the profiles for positions D, E, G, H and I (previously found to be in low standard deviation areas) are listed in Table III. As before, the differences between the individual climatologies and the mean temperature profile are normalized. These normalized values are plotted in Figures 4a-e for each position.

An area analysis for error is performed as for high standard deviation positions. In the low standard deviation areas, FNCL showed less error than NAVOCL in every case except position I. For position I, NAVOCL had a 38% smaller error than FNCL, the reason for which is unknown to this investigator. For positions D, E, G and H the results are listed below. Percentages given are the percent of decreased error experienced by FNCL over NAVOCL.

Table 111. Comparison of FNWC and NAVOCL with mean for the zulu time period indicated. Differences are normalized. Number of observations upon which the mean is calculated is given in parenthesis.

Position D

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (6) (3)		FNCL-MEAN				NAVOCL-MEAN			
					Absolute		Normal		Absolute		Normal	
			0900	0912	0900	0912	0900	0912	0900	0912	0900	0912
00	25.5	22.5	24.5	24.4	1.0	1.1	.5	.6	2.0	1.9	1.0	1.0
100	24.8	21.8	22.9	23.2	1.9	1.6	1.0	.8	1.1	1.4	.6	.7
200	21.3	20.3	21.3	21.3	.0	.0	.0	.0	1.0	1.0	.5	.5
300	20.2	18.8	20.2	20.2	.0	.0	.0	.0	1.4	1.4	.7	.7
400	19.6	18.6	19.7	19.5	.1	.1	.0	.0	1.1	.9	.6	.5
600	18.9	18.0	19.0	18.9	.1	.0	.0	.0	1.0	.9	.6	.5
800	18.4	17.8	18.6	18.5	.2	.1	.1	.0	.8	.7	.4	.4
1200	17.7	17.5	17.7	17.8	.0	.1	.0	.0	.2	.3	.1	.2

Position E

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (4) (8)		FNCL-MEAN				NAVOCL-MEAN			
					Absolute		Normal		Absolute		Normal	
			1000	1012	1000	1012	1000	1012	1000	1012	1000	1012
00	25.9	23.9	24.2	24.1	1.7	1.7	.5	.5	.3	.3	.1	.1
100	25.9	22.5	22.4	22.8	3.5	3.1	1.0	1.0	.1	.3	.0	.1
200	21.9	21.4	21.1	21.7	.8	.2	.2	.0	.3	.3	.1	.1
300	20.6	20.4	20.0	20.8	.6	.2	.1	.0	.4	.4	.1	.1
400	19.8	20.0	19.7	20.0	.1	.2	.0	.0	.3	.0	.1	.0
600	18.9	18.9	18.7	18.7	.2	.2	.0	.0	.2	.2	.0	.0
800	18.3	18.0	18.1	18.2	.2	.1	.0	.0	.1	.2	.0	.0
1200	17.6	17.5	17.4	17.4	.2	.2	.0	.0	.1	.1	.0	.0

Position G

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (18) (9)		FNCL-MEAN				NAVOCL-MEAN			
					Absolute		Normal		Absolute		Normal	
			1100	1112	1100	1112	1100	1112	1100	1112	1100	1112
00	25.4	21.4	24.3	23.9	1.1	1.5	.4	.4	1.9	2.5	.8	.7
100	25.4	20.2	22.4	21.9	3.0	3.5	1.0	1.0	2.2	1.7	.7	.5
200	21.6	19.7	20.9	20.6	.7	1.0	.2	.3	1.2	.9	.4	.3
300	20.4	18.8	20.2	19.8	.2	.6	.1	.2	1.4	1.0	.5	.3
400	19.7	18.5	19.7	19.2	.0	.5	.0	.1	1.2	.7	.4	.2
600	18.6	18.0	18.8	18.2	.2	.4	.1	.1	.8	.5	.3	.2
800	18.0	17.9	18.3	17.9	.3	.1	.1	.0	.4	.0	.1	.0
1200	17.3	17.3	17.5	17.1	.2	.2	.1	.0	.2	.2	.0	.0

Position H

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (2) (9)		FNCL-MEAN				NAVOCL-MEAN			
					Absolute		Normal		Absolute		Normal	
			1200	1212	1200	1212	1200	1212	1200	1212	1200	1212
00	24.0	20.0	23.8	25.4	.2	1.4	.0	.2	3.8	5.4	1.0	1.0
100	24.0	19.0	22.2	22.8	1.8	1.2	.5	.2	3.2	3.8	.8	.7
200	20.3	18.7	20.6	21.1	.3	1.8	.1	.3	1.9	3.4	.5	.6
300	19.4	18.3	19.9	20.6	.5	1.2	.1	.2	1.3	2.3	.4	.4
400	18.8	18.0	19.4	20.2	.6	1.4	.2	.2	1.4	2.2	.4	.4
600	18.1	17.8	18.3	18.7	.2	.6	.0	.1	.5	.9	.1	.2
800	17.8	17.1	17.6	17.8	.2	.0	.0	.0	.0	.5	.0	.0
1200	17.2	17.0	16.6	17.2	.6	.0	.2	.0	.4	.2	.1	.0

Position I

Depth (ft)	FNCL (°C)	NAVOCL (°C)	MEAN (3)	FNCL-MEAN		NAVOCL-MEAN	
				Absolute	Normal	Absolute	Normal
			1300	1300	1300	1300	1300
00	25.1	23.2	24.9	.2	.1	1.7	1.0
100	25.1	22.5	23.4	1.7	1.0	.9	.5
200	22.2	21.9	21.7	.5	.3	.2	.1
300	20.9	21.1	21.1	.2	.1	.0	.0
400	20.1	20.3	20.4	.3	.1	.1	.0
600	18.7	18.6	18.6	.1	.0	.2	.1
800	17.9	17.9	17.7	.2	.1	.2	.1
1200	16.9	16.7	16.7	.2	.1	.0	.0

Figure 4A. Normalized difference between FNCL and NAVOCL and the mean temperature profile for position D.

Figure 4B. Normalized differences between FNCL and NAVOCL
and the mean temperature profile for position E.

Figure 4C. Normalized difference between the mean temperature profile and the NAVOCL and FNCL for position G.

Figure 4D. Normalized difference between mean temperature profile and the FNCL and NAVOCL for position H.

Figure 4E. Normalized difference between mean temperature profile and the NAVOCL and FNCL for position I.

POSITION	FIRST FORECAST PERIOD	SECOND FORECAST PERIOD
D	70%	75%
E	30%	55%
G	37%	1%
H	82%	53%

As with the high standard deviation areas, FNCL is considered a better approximation to the mean temperature profile than NAVOCL based upon the strong trend observed.

2. Acoustic Predictions

Comparisons of temperature profiles and related conclusions about their validity is insufficient for a complete analysis. Since temperature profiles are not the final product, analyses of the acoustic prediction based on each profile are warranted.

Several methods of comparison of the acoustic prediction based on climatology and the mean BT data are available. The parameter used by the fleet for any such analysis is range; therefore, this analysis will center on predicted range. The standard set of input data for use with the propagation loss program are:

wave height = one foot,
 frequency = 60 Hz,
 source depth = 60 feet,
 receiver depth = 60 feet.

With this approach all remaining parameters (bottom depth and bottom roughness) are held constant except the temperature profile. This allows for a comparison of the affects that various separate temperature profiles have on acoustic propagation.

The publication, ASW Oceanographic Environmental Services (NAVAIR 50-1G-24, 1973) explains the method and logic behind the figure

of merit (FOM) determination from a propagation loss curve. This procedure is followed here with a FOM value of 90 db/ μ bar assumed for all cases. Using the ordinate value of 90 db as a guide, the range to the first intersection with the propagation loss curve is called the direct path range. Should convergence zone influence be strong enough, the 90 db line curve will intersect the propagation loss curve at least twice more. The range between the second and third intersection is the width of the convergence zone or annulus, and the range from the source to the leading edge of the annulus is the range to the first convergence zone. Figure 5 shows an example of the method for range determination. These three values are of tactical importance to the fleet; thus, they are pertinent analysis parameters.

Table IV is constructed for positions B and J, two positions in areas of high standard deviation, and H and E, two positions in areas of low standard deviation. Ranges for the above three parameters are given. Clark (FNWC, personal communication) indicates that due to a computer roundoff of range information, accuracy only to the nearest nautical mile can be expected. No greater accuracy is claimed nor possible by normal computer output means. Such conditions force the use of a band of ranges vice a single range. Compatibility of either climatology acoustic forecast with the acoustic forecast based on the mean temperature profile is achieved should any portion of the band of ranges computed from a climatology coincide with any portion of the band of ranges computed from the mean temperature profile.

Table IV. Acoustic range analysis for high standard deviation positions (B and J) and low standard deviation positions (H and E). (I) indicates incompatibility and (C) indicates compatibility with ranges as computed from the mean ET profile.

Position B FOM = 90 db				
Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ(nm)	Width of Annulus(nm)
MEAN	0800	2 - 4	35 - 37	1 - 3
FNCL	0800	21 - 23 (I)	35 - 37(C)	1 - 3(C)
NAVOCL	0800	21 - 23 (I)	34 - 36(C)	1 - 3(C)
MEAN	0812	21 - 23	34 - 36	1 - 3
FNCL	0812	21 - 23 (C)	35 - 37(C)	1 - 3(C)
NAVOCL	0812	21 - 23 (C)	34 - 36(C)	1 - 3(C)

Position J FOM = 90 db				
Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ(nm)	Width of Annulus(nm)
MEAN	1100	16 - 16	No CZ	NA
FNCL	1100	5 - 7 (I)	34 - 36(I)	1 - 3(I)
NAVOCL	1100	2 - 4 (I)	36 - 38(I)	1 - 3(I)
MEAN	1112	2 - 4	34 - 36	1 - 3
FNCL	1112	2 - 4 (C)	34 - 36(C)	1 - 3(C)
NAVOCL	1112	2 - 4 (C)	36 - 38(C)	1 - 3(C)

Position H FOM = 90 db				
Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ(nm)	Width of Annulus(nm)
MEAN	1200	0	34 - 36	1 - 3
FNCL	1200	5 - 7 (I)	34 - 36(C)	1 - 3(C)
NAVOCL	1200	0 (C)	37 - 39(I)	1 - 3(C)
MEAN	1212	0	34 - 36	1 - 3
FNCL	1212	0 (C)	34 - 36(C)	1 - 3(C)
NAVOCL	1212	0 (C)	37 - 39(I)	1 - 3(C)

Position E FOM = 90 db				
Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ(nm)	Width of Annulus(nm)
MEAN	1000	2 - 4	34 - 36	1 - 3
FNCL	1000	4 - 6 (C)	34 - 36(C)	1 - 3(C)
NAVOCL	1000	2 - 4 (C)	34 - 36(C)	1 - 3(C)
MEAN	1012	2 - 4	34 - 36	1 - 3
FNCL	1012	4 - 6 (C)	34 - 36(C)	1 - 3(C)
NAVOCL	1012	2 - 4 (C)	34 - 36(C)	1 - 3(C)

Figure 5. FOM determination of range from a propagation loss curve. A FOM value of 80 db/ μ bar is used for this case.

Despite the relative superiority of FNWC temperature profiles for positions B, H and E, it is necessary to analyze the three range predictions separately since different influences affected the development of each. In this way, errors inherent in each system can be examined.

For position H, a low standard deviation area, the direct path range from NAVOCL is compatible with the mean, but not so for the FNCL direct path range. At position E compatibility exists at all ranges for both climatologies. The high standard deviation positions, B and J, show compatible direct path ranges in the final forecasts, but are incompatible in the initial forecast.

3. Discussion of Results ✓

One of the main contributors to the magnitude of the direct path range is the thickness of the MLD. For example, Harvey (1972) shows that at 1700 Hz the energy loss for a MLD of 100 feet is 2.3 db/nm whereas for a MLD of 200 feet the loss is 1.3 db/nm. This MLD thickness effect is significant since over a typical direct path range of 5 nm, 5 db difference occurs. Thus an error in MLD thickness of a few tens of feet can appreciably alter a forecast. Also, the MLD is a function of space and time. Figure 6 shows the MLD from analysis of BT data taken in SEACONEX. The crosshatched area depicts the MLD. Both time and range effects are present. The cross-section was composed of BT data collected at different times and places. The horizontal distance was 32 nm and a time of two hours to travel the distance. The variability of the thickness of the MLD is clearly shown. In places, a change of 50 feet in the MLD can occur over a distance of only a single nautical mile.

Figure 6. Isotherms for Position B at a constant latitude. The MLD is denoted by the crosshatched isotherm layer. All BT data were taken during a two hour time period. Isotherms are in $^{\circ}\text{C}$.

Because of its larger data base, the FNCL was expected to show a better correlation to the actual mean MLD than did NAVOCL. In general, the temperature profile analysis supports this. Yet, since direct path range is a strong function of MLD (Urlick, 1967), the acoustic forecast indicates no such superiority. Neither climatology showed any superiority in acoustic compatibility. For positions B, J, and E almost identical records of compatibility are achieved. Only for position H did a discrepancy exist.

Any climatology is, in essence, a mean with an associated standard deviation. The actual real-time MLD could lie anywhere within certain limits about that mean MLD. The size of the limits is dependent upon the magnitude of the standard deviation. For example, should the distribution of MLD be Gaussian, there would be a 68% probability that the actual MLD would lie within one standard deviation of the mean MLD. The actual MLD then will lie within an envelope about the mean MLD.

For a short time period, e.g., one or two days, the actual MLD can lie anywhere within that envelope. As long as the FNCL and the NAVOCL acoustic predictions lie within that envelope, they have equal chance of correlation to the actual MLD. Over a long time period the actual MLD will vary about the mean MLD. It is the opinion of this investigator that even though a particular climatology over a long time period may provide a better representation of the actual MLD than another climatology, over any short time period no superiority is observed. Direct ranges predicted by any climatology must be considered as a "first guess" until additional data is available.

The range to the first convergence zone and width of the annulus is a function of the shape of the SVP and the magnitude of the gradient of the thermocline. Again it is expected that the larger data base and more sophisticated thermal structure of FNCL would allow the ranges associated with it to be closer than the ranges associated with NAVOCL when compared with ranges obtained by the actual mean temperature profile. As with the direct path case, no such superiority was seen in the acoustic range predictions. For these ranges, the FNCL showed excellent compatibility with the mean at all positions except the initial forecast of position J. Even for this case, the ranges forecasted were no farther from the mean forecast than those of NAVOCL. For the NAVOCL, incompatibility is experienced at positions H and J.

Again this investigator considers that conditions on a daily basis are too variable for either climatology SVP to yield consistently better results than the other. Local effects could influence the mean temperature profile significantly from the climatological mean. On the average the results of any correlation between any two ranges is considered only a temporary effect and not to be expected for subsequent reports. This is seen for position J, which has no correlation for FNCL in the first forecast, but exact matching in the second. Figure 6 shows a tongue of cold water that extends from depth to near surface. According to Nan-Titi (1967), this tongue may be only a local, short-lived effect (a few days) that would be reflected in a local mean but not in the climatology. This is further evidence that a monthly mean cannot be expected to correlate exactly with daily observations.

This investigator believes that for the purpose of daily forecasting no advantage is gained from the sophisticated approach to climatology used by FNWC for the case of a transiting ship. Should a lengthy time (30 days or more) be spent in a single area, the FNCL forecast may prove to give better results than NAVOCL. When only a few days are spent in an area, the daily fluctuations about the average will make correlations with any climatology only a chance effect.

C. SYNOPTIC COMPARISON

1. FNWC Synoptic Temperature Profile

Every BT taken during "SEACONEX" was sent to FNWC, where it was then included in the mean synoptic temperature profile as explained in Chapter I. Propagation loss curves were run for the positions of interest (same positions as used in previous climatology analysis) for each 12-hour analysis period.

The FNWC thermal analysis forecast at 0000Z is intended to be valid during the period 0000Z-1200Z. This profile was compared to the mean of all BT's taken during the interval 0000Z-1200Z. This mean, constructed of on-scene BT's, was considered to be the actual mean for the period. The same procedure is used for the 1200Z forecast. No control is placed on the generation of the mean profile in that all BT's are included and no weighting or biasing is used.

Table V lists the temperature profile as analyzed by FNWC for the time periods indicated. The notation in the table 0600Z should be interpreted as 0000Z on the sixth of June. A major

Table V. Temperature (C) at various levels for FNWC mean temperature profile and the actual mean temperature profile. The difference between the two are also given. Zulu time periods are given.

Position A

Depth (ft)	FNWC mean 0600Z	Actual mean 0600Z	Difference FN-Actual 0600Z
00	24.8	24.7	0.1
100	21.0	23.1	-2.1
200	19.8	21.7	-1.9
300	18.8	20.7	-1.9
400	18.6	19.8	-1.2
600	18.1	18.9	-0.8
800	17.6	18.5	-0.9
1200	17.3	18.6	-0.3

Position B

Depth (ft)	FNWC mean				Actual mean				Difference FN-Actual			
	0800	0812	0900	0912	0800	0812	0900	0912	0800	0812	0900	0912
00	24.5	25.0	25.0	24.8	25.1	25.1	25.0	25.0	-0.6	-0.1	-0.0	-0.2
100	24.3	24.0	23.0	24.0	23.0	23.6	22.9	24.2	-1.3	-0.4	-0.1	-0.2
200	21.8	20.7	20.9	20.5	21.6	21.3	20.7	23.1	0.2	-0.6	0.2	-2.6
300	20.2	19.7	19.9	19.5	20.7	20.5	20.5	22.0	-0.5	-0.8	-0.6	-2.5
400	19.9	19.1	19.6	19.2	20.2	20.0	19.6	20.3	-0.3	-0.9	-0.0	-1.1
600	19.3	18.5	19.0	18.5	19.5	19.2	19.2	19.1	-0.2	-0.7	-0.2	-0.6
800	19.1	18.0	18.5	18.0	18.9	18.5	18.7	18.8	0.2	-0.5	-0.2	-0.8
1200	18.8	17.0	17.7	17.6	18.3	17.5	17.8	17.8	0.5	-0.5	-0.1	-0.2

Position E

Depth (ft)	FNWC mean		Actual mean		Difference FN-Actual	
	1000Z	1012Z	1000Z	1012Z	1000Z	1012Z
00	25.0	24.7	24.2	24.2	0.8	0.5
100	22.8	23.2	22.4	22.8	0.4	0.4
200	21.4	21.7	21.1	21.7	0.3	0.0
300	21.0	21.2	20.0	20.8	1.0	0.4
400	20.6	20.5	19.7	20.0	0.9	0.5
600	20.3	19.1	18.7	18.7	1.6	0.4
800	19.2	18.1	18.1	18.2	1.1	-0.1
1200	18.3	17.8	17.4	17.4	0.9	0.4

Position D

Depth (ft)	FNWC mean		Actual mean		Difference FN-Actual	
	0900	0912	0900	0912	0900	0912
00	25.5	24.8	24.5	24.4	1.0	0.4
100	23.7	23.8	22.9	23.2	0.8	0.6
200	22.3	21.7	21.3	21.3	1.0	0.4
300	21.4	20.9	20.2	20.2	1.2	0.7
400	20.6	20.4	19.7	19.5	0.9	0.9
600	19.7	19.5	19.0	18.9	0.7	1.6
800	19.1	18.7	18.6	18.5	0.5	0.2
1200	17.9	17.8	17.7	17.8	0.2	0.0

Position C

Depth (ft)	FNWC mean		Actual mean		Difference FN-Actual	
	1100Z	1112Z	1100Z	1112Z	1100Z	1112Z
00	24.6	23.7	24.3	23.9	0.3	-0.3
100	23.3	22.9	22.4	21.9	0.9	1.0
200	21.2	21.0	20.9	20.6	0.3	0.4
300	20.3	20.1	20.2	19.8	0.1	0.3
400	19.5	19.4	19.7	19.2	-0.2	0.2
600	18.0	18.5	18.8	18.2	-0.8	0.3
800	17.3	17.9	18.3	17.9	-1.0	0.0
1200	16.6	16.7	17.5	17.1	-0.9	-0.4

Position I

Depth (ft)	FNWC mean 1300Z	Actual mean 1300Z	Difference FN-Actual 1300Z
00	24.9	26.0	-1.1
100	23.8	24.7	-0.9
200	21.7	22.5	-0.8
300	21.1	20.8	0.3
400	20.4	19.8	0.6
600	18.8	18.3	0.8
800	17.7	17.9	-0.2
1200	16.7	17.1	-0.4

Position H

Depth (ft)	FNWC mean		Actual mean		Difference FN-Actual	
	1200Z	1212Z	1200Z	1212Z	1200Z	1212Z
00	23.1	23.3	23.8	25.4	-0.7	-2.1
100	22.8	21.9	22.2	22.8	0.6	-0.9
200	22.0	20.5	20.6	21.1	1.4	-0.6
300	20.8	19.7	19.9	20.6	0.9	-0.9
400	19.2	19.1	19.4	20.2	-0.2	-0.9
600	18.0	18.5	18.3	18.7	-0.3	-0.2
800	17.4	18.1	17.6	17.8	-0.2	0.3
1200	16.3	17.3	16.6	17.2	-0.3	0.1

Position J

Depth (ft)	FNWC mean 1112Z	Actual mean 1112Z	Difference FN-Actual 1112Z
00	23.4	23.3	-0.1
100	22.3	22.3	0.0
200	20.5	19.8	0.7
300	19.8	18.9	0.9
400	19.3	18.8	0.5
600	18.5	18.5	0.5
800	17.8	17.7	0.1
1200	16.3	17.2	-0.9

contribution to this profile, according to Chapter II, is the BT's taken in "SEACONEX." However, BT's taken during the 0000Z-1200Z period are not utilized by FNWC until the 1200Z analysis. Thus the influence of BT's taken during one forecast period is not felt until the next forecast period. Conditions that influenced those BT's may not be present during the next forecast period. Hesse (1973) suggested that ideally as more BT data are sent to FNWC to be included in the mean temperature profile, the analyzed mean should better approximate the actual mean temperature profile. On the premise that temperature changes in the ocean are slow (Nan-Titi, 1967) the BT data sent to FNWC could be used despite the time lapse between taking a BT and its utilization.

One way to test the validity of the assumption that increasing the BT data base for FNWC analyses will force the temperature profile to converge to the actual temperature profile, is to compare two actual forecasts for the same position. Table V shows the difference between the FNWC mean temperature profile and the actual mean profile. According to the above assumption, this difference should decrease with each succeeding forecast. Figure 7 is a plot of the difference between the FNWC mean temperature profile and the actual mean temperature profile.

Only for position E can a definite pattern be seen for convergence at all eight levels, i.e., at all levels the difference values for the later analysis were smaller than those for the initial analysis. For positions B, D, G and H 46% of all observations showed a greater difference in the later analysis as compared to the preceding one. Conversely, 45% have a lesser difference and 9% experience

Figure 7A. Differences between FNWC mean temperature profile and actual mean temperature profile are plotted for the time periods indicated at position B.

Figure 7B. Difference between FNWC mean temperature profile and actual mean temperature profile are plotted for time periods indicated at position D.

Figure 7C. Differences between FNWC mean temperature profile and actual mean temperature profile are plotted for the time periods indicated at position G.

Figure 7D. Differences between FNWC mean temperature profile and actual mean temperature profile are plotted for the time periods indicated at position H.

Figure 7E. Differences between FNWC mean temperature profile and actual mean temperature profile are plotted for the time periods indicated at position E.

no change. No pattern of general divergence or convergence for any level can be established.

Limited data do not allow any definitive conclusions as to convergence or divergence. The data that are available show that even in areas of small temperature variability, the assumption that convergence to the mean temperature profile can be expected with increasing data is unfounded. Apparently the problem of time delay from observation to data input by FNWC is critical. The temperature profile analysis is updated by FNWC every 12 hours. Therefore, any BT's taken could be delayed up to 12 hours or more before entry into the analysis. Small scale, local anomalies, which may have influenced the BT, can change rapidly making the BT information erroneous. This is compounded by the problem of a transiting ship since a spatial change will also come into effect.

2. FNWC Acoustic Forecast

Propagation loss profiles for positions H, E and B were used to establish a range analysis based on the FNWC synoptic mean temperature profile and the actual mean temperature profile. The procedure was similar to that used in Chapter II. According to Figure 7, at position B the temperature profile converged for the upper 100 feet, but was divergent below 100 feet. Position H was an irregular profile of convergence and divergence. An entirely convergent pattern was experienced at position E. Analysis of these different temperature patterns will permit one to study the effects that different profiles have on the acoustic ranges.

Table VI shows the forecasted acoustic ranges based upon actual mean temperature profiles and FNWC mean profiles. All FNWC

Table VI. Range compatibility between acoustic forecasts based on a mean synoptic temperature profile and the FNWC mean temperature profile. (C) denotes compatibility, (I) denotes incompatibility.

Position B FOM = 90 db

Acoustic Prediction Based Upon	Forecast Time Period	Direct Path(nm)	First CZ(nm)	Width of Annulus(nm)
BT Mean	0800	2 - 4	35 - 37	1 - 3
FNWC Mean	0800	21 - 23 (I)	35 - 37 (C)	1 - 3 (C)
BT Mean	0812	21 - 23	34 - 36	1 - 3
FNWC Mean	0812	21 - 23 (C)	34 - 36 (C)	1 - 3 (C)

Position H FOM = 90 db

Acoustic Prediction Based Upon	Forecast Time Period	Direct Path(nm)	First CZ(nm)	Width of Annulus(nm)
BT Mean	1200	0 - 1	34 - 36	1 - 3
FNWC Mean	1200	0 - 1 (C)	34 - 36 (C)	1 - 3 (C)
BT Mean	1212	0 - 1	34 - 36	1 - 3
FNWC Mean	1212	0 - 1 (C)	35 - 38 (C)	3 - 5 (C)

Position E FOM = 90 db

Acoustic Prediction Based Upon	Forecast Time Period	Direct Path(nm)	First CZ(nm)	Width of Annulus(nm)
BT Mean	1000	2 - 4	34 - 36	1 - 3
FNWC Mean	1000	2 - 4 (C)	34 - 36 (C)	1 - 3 (C)
BT Mean	1012	2 - 4	34 - 36	1 - 3
FNWC Mean	1012	2 - 4 (C)	34 - 36 (C)	1 - 3 (C)

forecasts were based on at least one BT taken in "SEACONEX." An analysis similar to the one for ranges based on climatology in Chapter II Section B.2 was used. An envelope of ranges was considered for the three parameters of direct path range to the first convergence zone and width of the convergence zone annulus. By definition compatibility is achieved should any part of one forecast band overlap with the other.

Position B indicates a considerable error in the direct path range for the initial forecast period, but compatibility is achieved for the range to the first convergence zone and width of the annulus. By the time of the second forecast, compatibility is achieved for all ranges. Positions H and E show complete compatibility at all times and ranges.

These developments indicate that regardless of whether temperature profiles converge or diverge to a mean, once FNWC has received several (more than one) BT's from an area the ranges predicted are generally compatible with those based on a mean synoptic profile. Compatibility cannot be assumed for a single BT input as seen for position B which was based upon only a single BT input. The direct path range was incompatible with the mean direct path range. All later forecasts were based upon at least two (forecasts.) P~ Since complete compatibility was observed for these later forecasts, it is expected that ranges predicted by FNWC are reliable within roundoff error limits, provided at least two BT's have been input into the analysis.

III. ICAPS I/O ANALYSIS

A. TEMPERATURE INPUT

ICAPS operates on a single BT input upon which the acoustic propagation loss profile is generated. In order to establish how much reliability can be assigned to a single BT, Table VII is presented. For the construction of this table, BT's taken at each position are averaged and a variance is calculated for every level. Four positions, B, D, E and G, have a variance (σ^2) greater than 1.0°C for at least one level. Positions H and I have at least one level which has a variance greater than 0.5°C. Thus only three of nine positions show a variance at all levels less than 0.5°C.

The above analysis indicates that in all geographic positions examined, a high degree of thermal structure variance was present. Thus at a given location the temperature profile can vary significantly over a relatively short period of time. A change of 0.5 to 1.0 degrees centigrade at various levels can alter the MLD and the gradient of the thermocline presenting different characteristics for separate profiles.

(Figure 6 shows that over a very short distance of the ocean the temperature profile can vary considerably. For the profile taken at position 1 a 40 foot MLD and a moderately steep thermocline are observed. At position 2 the trace shows no MLD and a slightly steeper thermocline. The separation between the stations is only two nautical miles and 8 minutes in space and time.

Table VII. Variances (σ^2) calculated for all positions based on actual BT data taken in "SEACONEX".

Position A		Position B		Position C	
Depth (ft)	σ^2	Depth (ft)	σ^2	Depth (ft)	σ^2
00	.38	00	.14	00	.28
100	.17	100	2.07	100	.17
200	.45	200	.44	200	.05
300	.14	300	.28	300	.04
400	.18	400	.38	400	.15
600	.05	600	.17	600	.00
800	.04	800	.17	800	.01
1200	.04	1200	.17	1200	.02

Position D		Position E		Position G	
Depth (ft)	σ^2	Depth (ft)	σ^2	Depth (ft)	σ^2
00	.22	00	.10	00	.39
100	.60	100	.96	100	1.95
200	1.08	200	1.08	200	1.15
300	.39	300	.70	300	.80
400	.26	400	.68	400	.52
600	.30	600	.70	600	.34
800	.21	800	.69	800	.12
1200	.20	1200	.06	1200	.26

Position H		Position I		Position J	
Depth (ft)	σ^2	Depth (ft)	σ^2	Depth (ft)	σ^2
00	.33	00	.11	00	.02
100	.40	100	.92	100	.16
200	.30	200	.17	200	.02
300	.53	300	.10	300	.09
400	.51	400	.22	400	.06
600	.07	600	.07	600	.00
800	.14	800	.02	800	.02
1200	.28	1200	.05	1200	.06

Effects of internal waves, turbulence, and local anomalies can be expected to affect any BT profile. The mean temperature profile of an area is considered as the best representation of the area, but the various influences present can limit any single profile in its correlation to that mean. Figures 8a,b and c are constructed to show the relationship between a mean profile and the individual BT's that were used to establish it. Positions A and H show significant differences between BT's with respect to gradient and gradient changes. For the most part there is little similarity to the mean for any single profile. For position B, curves (4), (2) and (3) do exhibit fairly uniform and reasonable similarity to one another and to the mean. Below 400 feet all profiles have a gradient very close to $0.3^{\circ}\text{C}/100$ feet. Even for this case, curve (1) has a MLD of 100 feet while the mean profile does not exhibit any MLD.

If the mean temperature profile is assumed to be a reliable estimate for the true mean profile in an area, this investigator concludes that a single BT is generally an unreliable estimate of the mean temperature profile for an area.

✓ B. ICAPS ACOUSTIC OUTPUT

As with analysis of climatological and synoptic information, temperature analysis alone is inconclusive. The acoustic information generated by the profiles, being the end product, is the final rule against which correlation is measured.

Table VIII is constructed for positions A, B, and H of which the first two are positions of high standard deviation and the latter of low standard deviation. Using the same analysis for range

Figure 8A. Temperature profiles for the mean and single BT's are given for position II.

Figure 8B. Temperature profiles for the mean and single BT's are given for position B.

Figure 8C. Temperature profiles for the mean and single BT's are given for position A.

Table VIII. Single BT input to ICAPS acoustic ranges versus the acoustic ranges for the actual mean temperature profile. (C) denotes compatibility, (I) denotes incompatibility.

Position B FOM = 90 db

Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ (nm)	Width of Annulus (nm)
ICAPS				
Single BT	0812	1 - 3 (C)	35 - 37 (C)	4 - 6 (C)
Mean	0812	1 - 3	35 - 37	4 - 6

Position A FOM = 90 db

Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ (nm)	Width of Annulus (nm)
ICAPS				
Single BT	0600	1 - 3 (C)	33 - 35 (C)	1 - 3 (C)
Mean	0600	2 - 4	34 - 36	1 - 3

Position H FOM = 90 db

Acoustic Prediction Based Upon	Forecast Time Period	Direct Path (nm)	First CZ (nm)	Width of Annulus (nm)
ICAPS				
Single BT	1200	1 - 3 (C)	34 - 36 (C)	1 - 3 (C)
Mean	1200	0 - 2	34 - 36	1 - 3

as used previously, it is seen that for the three cases generated, complete compatibility for the acoustic ranges is experienced.

✓ This investigator concludes that at least for the cases shown, a single BT can be a reliable indicator for acoustic ranges. The variability in temperature profiles has little influence over the acoustic transmission loss. (Clark (FNWC, personal communication) indicated that low frequency signals tend to be little effected by minor changes in the temperature profile.) In other words, minor changes in the profile are smoothed out when a low frequency signal is transmitted. Consequently, the influences of small scale perturbations in the temperature profile will not be realized for low frequencies. As long as profiles have the same general shape, approximately equal detection ranges can be expected.

✓ With such a small statistical base, conclusions covering any large scale area are unfounded. Yet the evidence that is available does indicate that for the most part in any single area, a single BT input can furnish the ICAPS operator with reliable range data. The ranges calculated can at least be used as a good first approximation to those of the mean within normal error limits.

IV. CONCLUSIONS

A. CLIMATOLOGY

The data presented show that for a large percentage of areas, the FNWC climatological temperature profile appeared to be closer to the mean temperature profile for the studied areas than the climatology developed and used by NAVOCEANO for the ICAPS computer for the exercise "SEACONEX." It should be remembered that this NAVOCEANO climatology was only meant as a first attempt until a more sophisticated model could be developed. However, low frequency acoustical forecasts based upon either climatology do not indicate a clear preference for one system over the other. While local mean temperature profiles will smooth, but still incorporate, local anomalies, low frequency sound will not respond to small temperature fluctuations.

This investigator concludes that for a short time period the assumptions that FNWC climatology will yield more reliable acoustic ranges than NAVOCEANO climatology is unfounded. A transiting naval ship can expect nearly the same results from a sophisticated climatology as well as from a simple one. Forecasts based on climatology alone should be used only as an initial approximation and only for information purposes. The probability that the predicted ranges will reflect actual conditions are uncertain.

B. SYNOPTIC

✓ FNWC synoptic temperature profiles show no overall evidence of convergence to a mean temperature profile. Yet, within limits of

roundoff error, the ranges forecast by FNWC based upon at least two BT's proved to be similar to that based upon the mean BT profile. It is concluded that FNWC synoptic forecasts do indeed provide a reliable tactical forecast.

The single BT input for ICAPS has proven to be a reliable forecast agent. However, the user must attempt to calculate a mean temperature profile for his area as soon as possible. Until a mean profile is established, a single BT input may be used with moderate reliability.

C. OPERATIONAL CONSIDERATIONS

Based on information from "SEACONEX," the large time delay (up to 12 hours) between the time a BT was taken and incorporation in the temperature profile at FNWC and the time delay (average of two hours) between the time the FNWC forecast was made and receipt of the forecast, and the fact that in any combat situation, communications with FNWC will be minimal, the dependence upon FNWC to provide real-time forecasts to the fleet seems unrealistic. ICAPS utilizes the same acoustic models and inputs without the communications problems with a very short time delay. It is concluded that the ICAPS system is the appropriate real-time system, but FNWC can be used as an accurate backup system.

For tactical planning purposes, FNWC climatology should be used as the source of acoustical range information. Their large choice of data presentation techniques and ability to widely vary input parameters make them well suited to laying out the expected acoustic ranges for any area in a style best suited to the situation.

Greater detail and lesser roundoff error can be obtained by a proper choice of display. At present this option is not available to ICAPS. Also, this study showed that for short time periods, the superiority of any climatology versus another is unfounded. Yet for any longer period of consideration, the much more sophisticated climatology of FNWC as opposed to the interim climatology of NAVOCEANO should present more representative information.

V. RECOMMENDATIONS

A. STANDARD DEVIATION FIELDS

In order to supply the ICAPS operator with a scheme upon which to base reliability of his forecasts, it is suggested that NAVOCEANO compile Lewit's (1971) tables in such a way that the expected standard deviation from the mean temperature field for each acoustical area can be made operationally useful. A color code for large, moderate or small standard deviation fields is a simple but useful guide. Such a presentation will afford the operator an insight into how much variability can be expected in his area. Also, he could plan his data collection based on such a system, e.g. more BT's could be taken in areas of large standard deviation and fewer in areas of small standard deviation.

B. TRAINING OF ICAPS OPERATORS

NAVOCEANO and the ASW schools should conduct a short course on the proper operation of the ICAPS system. Ships equipped with ICAPS should be assigned trained oceanographers with a sense of appreciation for real-time problems and the art of good data collection and forecasting methods.

C. ALTERATIONS TO ICAPS SYSTEM

BT input should be recorded on a cassette tape for easy handling and recovery. Presently a profile must be hand digitized and entered into the computer. Also the program should be altered to allow for

the input of more than a single set of parameters at a time. The program could solve and display each set separately, which would save considerable time.

D. FNWC PROGRAM ALTERATIONS

Presently FNWC calculates a variable constant which is an indication of the rapidity with which the mean temperature profile may vary from its initial state (Clark, personal communication). This constant is based upon the data density (number of observations used to form the statistics), the sonic layer depth and the magnitude of the sound velocity gradient. The number is then simply sent to the user.

Two basic problems are noticed in this approach. Parameters such as expected standard deviation of the temperature profile, and actual roughness and slope of the bottom spatial and temporal variations in received BT profiles are not included in the program. More importantly, the user does not know which parameter exerted the major influence in the determination of the constant. For the first case, the program should be rewritten to include the three parameters listed since they exert a large effect on the variability of the acoustic profile. Secondly, for the latter problem, the user should be informed as to which parameter had the greatest influence on the forecast in order to enable him to better deal with the problem. A simple code could be established showing the degree of relative influence each had on the acoustic profile. In this way the usefulness of a single BT is enhanced in that a user would be able to judge as to the variability of the water column, spatial variation, and other parameters separately.

Therefore, it is the opinion of this investigator that the program be rewritten to include additional parameters such as those discussed above. Additionally, some method to inform the user of the most influential parameter should be developed.

APPENDIX A

FNWC SEA SURFACE TEMPERATURE ANALYSIS

The basis for the Fleet Numerical Weather Central's (FNWC) sea surface temperature analysis scheme is the Fields by Information Blending (FIB) program. Figure 9 shows a flow diagram for the FIB program. The analysis scheme requires a first guess temperature field, T_G , and a base field temperature, T_B . Figure 10 shows the area module for the program. Gradients are given as u and v with associated weights B^* and C^* (Holl et al, 1971).

The basis for T_G is the preceding analysis, $T_{-\tau}^*$, where τ is the analysis period, adjusted slightly toward climatology. The climatology, T_C , is computed as a weighted mean for each analysis. The weight assigned to the current month is one-half, and the preceding and following months have a combined weight of one-half, prorated by the hour of the month. Thus the equation for the first guess temperature is as follows:

$$T_G = (1-F) \cdot T_{-\tau}^* + F \cdot T_C$$

where F is proportional weight assigned to climatology (Holl et al, 1971).

In order to nullify the small scale anomalies, often caused by sparse data, a climatic smoothing is accomplished:

$$T_B = (T_G - T_C)_{\text{SMOOTHED}} + T_C$$

The first guess difference field, J_o , is given by

$$J_o = T_G - T_B \quad (\text{Holl et al, 1971})$$

Figure 9. Flow diagram for SST analysis

Figure 10. Grid diagram for SST analysis

Observations (subscript n) are transformed into difference values:

$$J_n = T_n - T_B. \text{ (Holl et al, 1971)}$$

Data preparation is a screening process designed to: (1) eliminate all reports not containing an SST value; (2) eliminate duplicate reports; (3) reject reports outside analysis region; (4) assign report reliability, A_N , (a function of the contributing variances); (5) perform an initial gross error check by analysis the magnitude of J_n ; and (6) reduce reports weights for quasi-duplication, that is, for non-identical reports from the same reporting platform (Holl et al, 1971).

During the assembly phase, each report is assembled at the nearest grid point. The report difference value, J_n , and its weight, A_N , are added to the accrued information at the grid point:

$$A_N = A_N + A_{N-1}$$

$$J_n = (A_N J_n + A_{N-1} J_{N-1}) / A_N.$$

N refers to the stage of the assembly and no to the single report (Holl et al, 1971).

The blending equation reduces to

$$J_{\ell,m} = S_{\ell,m}^{-1} [A_{\ell,m,N} J_{\ell,m,N} + \{B_{\ell,m}^* J_{\ell,m+1}^* + C_{\ell,m} J_{\ell+1,m} + B_{\ell,m-1}^* J_{\ell,m-1}^* + C_{\ell-1,m} J_{\ell-1,m}\}].$$

where S is defined by

$$S_{\ell,n} = A_{\ell,n} + B_{\ell,n}^* + C_{\ell,n}^* + B_{\ell,m-1}^* + C_{\ell-1,m}^*$$

A^* is solved for using the following equation:

$$A_{\ell,m}^* = A_{\ell,m} / A_{\ell,m}^{-1} / A_{\ell,m}^* - 1$$

If this is the first pass through the Assembly, J* Blending, and A* Solution phases, a gross error check is now made on each SST observation. All reports are re-evaluated considering the new J* field. Once again the accepted reports are assembled at the nearest grid point and the J* Blending and A* Solution phases are completed. This time the output is combined with the Base Field Temperature (T_B) to provide the analyzed sea surface temperature field (Holl et al, 1971).

APPENDIX B

FNWC MIXED LAYER DEPTH ANALYSIS

The FNWC mixed layer depth (MLD) analysis scheme is described by Hesse (1973). The MLD is defined as the lower boundary of the turbulent, mixed surface layer or the upper boundary of the thermocline. The potential mixed layer depth (POTMLD) is defined as the depth to which the turbulent mixed layer depth extends. It represents the mean MLD about which short-period fluctuations can be expected.

The model has three steps:

1. Adjusting the first guess--the 12-hour-old MLD analysis--climatology to form Guess 1.
2. Computing the effects of wave action on the MLD, and adjusting Guess 1 accordingly.
3. Adjusting the guess field (Guess 1) to available BT reports taken in last 72 hours.

In the actual program computations the analysis proceeds as follows:

1. $\text{Guess}_0 = 12\text{-hour-old POTMLD}$
 $\text{Guess}_1 = \text{Guess}_0 + 1/16 (\text{CLIMAT} - \text{Guess}_0)$, where
if day = 14, $\text{CLIMAT} = (0.5 - \text{day}/30) + (\text{day}/30 + 0.5)$,
if day = 15, $\text{CLIMAT} = \text{CLIMAT}$ for current month,
if 16 = day = 30, $\text{CLIMAT} = (1.5 - \text{day}/30) (\text{CLIMAT current month} + (\text{day}/30 - 0.5) (\text{CLIMAT next month}))$,
if day = 31, $\text{CLIMAT} = \text{same as for 30}$.

2. Compute MLD:

$$\begin{aligned}\text{MLD}_{\text{waves}} &= \text{CH}(11 - 0.1(\text{SST} - T_{600})), \text{ if } \text{SST} = T_{600} \\ &= \text{CH} \cdot 11 \text{ if } \text{SST} = T_{600}\end{aligned}$$

where CH = combined wave height,

SST = sea surface temperature,

T_{600} = temperature at 600 feet.

3. Smooth the guess field with a special smoother.
4. Force the guess field to be at least as deep as the MLD waves field:

$$\begin{aligned}\text{Guess}_2 &= \text{Guess}_1, \text{ if } \text{Guess}_1 \geq \text{MLD}_{\text{waves}} \\ &= \text{MLD}_{\text{waves}}, \text{ if } \text{Guess}_1 < \text{MLD}.\end{aligned}$$

5. Adjust Guess_2 field to BT reports.
6. Limit final analysis field by forcing $\text{POTMLD} = 900$ feet.

Figure 11A. Basic flow chart for sub-surface temperature analysis.

Figure 11B. Basis flow chart for sub-surface temperature analysis
(continued)

APPENDIX C

FNWC SUB-SURFACE TEMPERATURE ANALYSIS

The FNWC sub-surface temperature analysis is run at the 100, 200, 300, 400, 600, 800 and 1200 foot levels. The 12-hour old analysis is used as a starting point for each level. This is adjusted 1/16 of the way toward climatology. After this adjustment, the figures are further adjusted to the MLD and SST analysis to produce the guess field. The MLD and SST analysis serve as strong anchor points for the subsequent sub-surface analysis. (Hesse, 1973)

BT reports for the preceding 72-hour period are included in the analysis, and they are weighted by age on a 1 to 4 scale. At each level the report is subjected to a gross error check (GEC) by requiring that the report fall within limiting values of the guess field. A similar GEC is run on reported gradients by comparison with the guess field gradients. (Hesse, 1973)

The guess field is adjusted to all reports which passed the GEC. The vertical gradient between the first analysis and the final analysis from the level above is then slightly smoothed. Next, consistency is checked by allowing a positive temperature gradient to exist only at selected grid points. Finally, the temperature range at all levels is restricted to the range of -2 degrees to 35 degrees centigrade. Figure 10 shows the basic flow chart for the sub-surface analysis. (Hesse, 1973)

REFERENCES

1. Navair 50-IC-24. 1973. ASW oceanographic environmental service. COMNAVWEASERV, Wash. 130 p.
2. Consultec, Inc. 1972. Development plan for an integrated carrier acoustic prediction system (ICAPS). San Diego. 80 p.
3. Harvey, P. I. 1972. An analysis of environmental data for use in updating low frequency propagation loss forecasts. M. S. thesis. Naval Postgraduate School, Monterey. 184 p.
4. Hesse, E. 1973. New temperature products manual. Unpublished report. FNWC, Monterey.
5. Holl, M. M., B. R. Mendenhall, and C. E. Tilden. 1971. Technical developments for operational sea surface temperature analysis with capability for satellite data input. Meteorology International, Inc., Monterey. Project M-160. 46 p.
6. Lewit, H. L. 1971. List of standard deviations for ocean areas. Unpublished report. FNWC, Monterey.
7. N n-Niti, T. 1967. Some remarks on scale of time and length of phenomena for oceanic prediction. Jour. Oceanographic Soc. Japan., 23(2):86-87.
8. Naval Weather Service Command. 1971a. Ship, helicopter acoustic range prediction system (SHARPS II). Navweaservcom Inst 3160.2. 3 p.
9. _____. 1971b. Acoustic sensor range prediction system (ASRAP III). Navweasercom Inst 3160.3. 4 p.
10. Urlick, R. J. 1967. Principles of underwater sound for engineers. McGraw-Hill, New York. 342 p.
11. Wilson, W. D. 1960. Equation for the Speed of Sound in Sea Water. Jour. Acous. Soc. Am. 32(10):1357.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Naval Oceanographic Office developed the Integrated Carrier Acoustic Prediction System (ICAPS) in order to perform on-scene acoustic forecasts for the Fleet. To evaluate the system, bathythermographic information was obtained for points in the North Atlantic during the naval exercise "SEACONEX." Fleet Numerical Weather Central (FNWC) provided climatological and synoptic temperature profiles along with related acoustical forecasts for the points under study. Similarly, ICAPS supplied a combined climatological and synoptic		

temperature profile and related acoustic forecasts for each of the points. Comparisons of the two systems were made against an actual mean temperature profile and the acoustic forecast that it generated. It appears that the climatological acoustic forecasts were not reliable tactically. Yet the synoptic forecasts by FNWC did yield reliable low frequency acoustic forecasts within the limits of computer roundoff error. ICAPS capability for only a single temperature profile input proved to yield reliable acoustic forecasts, and should be used as the real-time acoustic forecast system for the Fleet.

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