PSR Report 922

EVALUATION OF STANDARD OCEAN CANDIDATES

J. G. Colborn
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F. J. Ryan

March 1980

Final Technical Report
Contract N00014-79-C-0310

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Sponsored by
Long-Range Acoustic Propagation Project
Naval Ocean Research and Development Activity
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PACIFIC•SIERRA RESEARCH CORP.

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Evaluates eight candidate models (AUTO-OCEAN, GDEM, ICAPS, ODSI, GFDL HYDAT, SIMAS) for Standard Ocean--a system to provide oceanographic and acoustic data in 1° × 1° oceanic squares, formatted for NORDA's numerical acoustic models and usable by nonspecialists. Meeting or exceeding most criteria were AUTO-OCEAN (outputs seasonal, RSVP-retrieved, extended sound-speed profiles in northern hemisphere 5° × 5° squares, as well as bathymetric, wave height, and bottom class data; rapid, inexpensive, and operational, but resolution still

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too coarse); and GDEM (not yet operational, but will provide northern hemisphere temperature [surface to 400 m], salinity [surface to 800 m], and sound-speed [surface to bottom] data on a 30' × 30' grid; output generally agrees with observations, but sometimes falls outside range of observed data, shows peculiar deep seasonal shifts, or misrepresents primary and secondary sound channels).

PREFACE

This is the Standard Ocean Evaluation Group's final report on its search for a data retrieval system that will be installed as Standard Ocean in the data bank of the Long Range Acoustic Propagation Project (LRAPP), sponsored by the Naval Ocean Research and Development Activity (NORDA). LRAPP formed the evaluation group in January 1979 to assemble a roster of candidate systems and evaluate each against project requirements. The group comprised J. G. Colborn, chairman (Naval Ocean Systems Center); S. C. Daubin, Jr. (Pacific-Sierra Research Corporation [PSR]); E. Hashimoto (NORDA); and F. J. Ryan (Ocean Data Systems, Inc. [ODSI]). Standard Ocean is to be installed early in FY 1981.

Preliminary results of the evaluation group's search were reported in a memorandum to Lcdr. Kirk Evans (NORDA) and John H. Locklin (ODSI) on 30 April 1979.* The present report reflects subsequent discussions held at NORDA, further evolution of the prime candidate model, GDEM, and recent evaluation efforts.

The draft of the report was submitted for review in August 1979 (results are current as of that date); the report was approved for distribution on 7 February 1980. In the interim, the following changes occurred: LRAPP was renamed the Surveillance Environmental Acoustic Support (SEAS) Project; and Fleet Numerical Weather Central (FNWC) is now called the Fleet Numerical Oceanography Center (FNOC). Readers will note that the text retains the former nomenclature. Also in the meantime, F. J. Ryan changed his affiliation to Science Applications, Inc.

The efforts of the following individuals at PSR contributed to this report: Christine D'Arc edited it; Joan Pederson typed it; Laurie Blackeby and Timothy Hadlock prepared the artwork.

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*"Preliminary Evaluation of Candidates for the Standard Ocean Retrieval System and Next Steps Toward Implementation."

SUMMARY

This report describes and evaluates eight existing or proposed oceanographic models as candidates for Standard Ocean, a data retrieval system to be installed in the Long Range Acoustic Propagation Project (LRAPP) data bank. The primary purpose of Standard Ocean is to provide range-dependent sound-speed profiles for input to NORDA's numerical acoustic models. Standard Ocean will also be used to support the objective analysis of environmental data collected during exercises at sea. The candidate systems and their parent organizations are as follows:

- AUTO-OCEAN (NORDA)
- FIB/EOTS/EXTRA (FNWC)
- GDEM (NAVOCEANO)
- ICAPS (NAVOCEANO)
- ODSI (Ocean Data Systems, Inc.)
- GFDL (Geophysical Fluid Dynamics Laboratory, NOAA, Princeton University)
- HYDAT (FNWC)
- SIMAS (NUSC/New London)

The Standard Ocean Evaluation Group assessed each candidate according to criteria indicated in the following description of desired Standard Ocean capabilities. Standard Ocean is to provide accurate, realistic, and seasonal (preferably monthly) surface-to-bottom profiles of sound speed, temperature, and salinity in each oceanic 1° × 1° square. The sound-speed profiles should be in a format suitable for numerical acoustic models. The profiles should accurately reproduce all acoustically significant features. The degree of oceanic variability in each square should be indicated. Standard Ocean should operate rapidly and inexpensively. It should be easily usable by the nonspecialist. Finally, the candidate chosen should be competitive in acquisition cost and availability.

Using those criteria, we found the following six candidates unsuitable for Standard Ocean: FIB/EOTS/EXTRA, GFDL, HYDAT, ICAPS, ODSI, and SIMAS. The remaining two, AUTO-OCEAN and GDEM, met or exceeded most Standard Ocean criteria. Nevertheless, each requires modification before it can be adopted as Standard Ocean. AUTO-OCEAN, an operational retrieval system, requires a finer grid spacing for its sound-speed profiles and the addition of temperature and salinity profiles as outputs. GDEM, an objective analysis model being developed, requires refinement of its objective analysis technique to remove anomalies in the middepth sound-speed profiles. The developer is redesigning part of GDEM to correct those faults. Completion of the GDEM analysis for the North Atlantic, North Pacific, and Mediterranean is expected by early FY 1981. The Indian Ocean portion is to be completed at an unspecified future time. Should GDEM not be ready by early FY 1981, the target date for installation of Standard Ocean, we recommend that AUTO-OCEAN be used in the interim, revised in key areas of LRAPP interest as indicated above. Even when GDEM is completed, we recommend storing the GDEM outputs in the AUTO-OCEAN framework to satisfy the requirement that acoustic model inputs be automated.

No candidate has the required capability of indicating oceanic variability. We recommend that LRAPP investigate how that capability could be developed for Standard Ocean after installation.

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I. INTRODUCTION

This report presents the results of a search for a data retrieval system to be installed as the Standard Ocean in LRAPP's data bank. The Standard Ocean Evaluation Group determined that eight systems warranted consideration as Standard Ocean candidates, and we examined each in light of LRAPP's requirements.

THE NEED FOR STANDARD OCEAN

Standard Ocean was conceived by Lcdr. Kirk Evans (NORDA) to meet LRAPP's need for the rapid retrieval of accurate, realistic range-dependent oceanographic data, primarily sound-speed data, for input in NORDA's numerical acoustic models. LRAPP uses those models for a variety of purposes including exercise preassessment, exercise post-analysis, and area assessments. Standard Ocean is also needed to provide inputs for the objective analysis of exercise environmental data.[*] Other potential users of Standard Ocean include Fleet Numerical Weather Central (FNWC), NORDA Code 320, and the oceanographic community at large.

Standard Ocean will furnish a variety of oceanographic data besides sound speed. It should be able to provide accurate, realistic surface-to-bottom profiles of sound speed, temperature, and salinity in each 1° × 1° square of the oceanic northern hemisphere. Each profile will be typical for a particular square in one of the four seasons (if attainable, monthly resolution is desired). The profiles will represent the most probable oceanographic conditions in the given square and time period. "Most probable" does not signify average or mean; though statistically correct, an average profile might never be observed in that location.

Standard Ocean will produce acoustically accurate sound-speed profiles. That is, sound-speed magnitudes, channel axes and layer

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[*] J. Locklin et al., *LRAPP Objective Analysis: A Review of Objective Analysis Schemes for the LRAPP Data Management Program*, LRAPP, 20 March 1979.

depths, and horizontal and vertical gradients should be those most likely to be observed at the location and time specified. The sound-speed profiles should be in a format suitable for numerical acoustic models.

Though not used directly in numerical acoustic models, temperature and salinity data are valuable for verifying the quality of the output that *is* used. The accuracy of sound-speed output cannot be determined from sound speed alone. Other more stable measures of accuracy are needed. Temperature and salinity change in highly predictable ways (i.e., away from the oceanic boundaries, heat and salt are not added or subtracted from the ocean except in the surface layer above 100 m, in some shallow areas, and to a much lesser extent on the ocean bottom). Therefore temperature and salinity data facilitate quality checks of model output, two common ones being (1) that density does not decrease with depth, and (2) that temperature versus salinity versus depth follow known empirical relationships.* Hence the need for temperature and salinity data in Standard Ocean.

The degree of oceanic variability in each square, though not of immediate concern to acoustic modelers, should eventually be added to Standard Ocean's capabilities. Over long periods, variability in the upper kilometer of the ocean can cause marked differences between predicted and observed conditions. For instance, the variability-caused "noise" in the observed surface temperature can be as great in amplitude as the annual signal. Variability outputs needed for Standard Ocean include measures of the incidence of sonic layers, their minimum and maximum depths, the incidence of eddies and fronts, and the minimum and maximum ranges of temperature, salinity, and sound-speed profiles.

Standard Ocean will be an automated system that a nonoceanographer/nonacoustician can use to quickly and cheaply select the appropriate sound-speed profiles for model runs. In effect, Standard Ocean will

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*The rationale for temperature and salinity analysis, and the procedures involved, are explained in greater detail in O. I. Mamayev, *Temperature-Salinity Analysis of World Ocean Waters*, Elsevier Oceanography Series, Vol. 11, Elsevier Press, Amsterdam, The Netherlands, 1975, and in Appendix F.

remove the oceanographer from the data selection "loop" and replace him with a computerized data retrieval system. The oceanographer's attention can thus be freed for model runs requiring more specialized inputs and interpretations.

Standard Ocean will function as a separate unit within the LRAPP data bank. Figure 1 depicts Standard Ocean's role in the flow of information from data sources to acoustic models. Environmental data from sources such as NODC and FNWC are screened and edited. Depending on the technique employed, either the most probable real profiles are selected, or all observed data are objectively analyzed to produce a smoothed, representative field. The analyzed data become the Standard Ocean. Next, the data are retrieved from Standard Ocean and combined with other environmental data such as shipping distributions and bathymetry for input first into the appropriate reformatting software and then into acoustic models such as PE, FACT, and ASTRAL. Alternatively, Standard Ocean can input data into the objective analysis module of the data bank and then into the reformatting modules and acoustic models. In that capacity, Standard Ocean provides the first-guess climatology necessary to initiate the objective analysis of a particular data set.

STANDARD OCEAN REQUIREMENTS

The foregoing description of the attributes desired in Standard Ocean yielded the following list of requirements, which we used to evaluate the candidate systems:

- *Output products and technical quality*. Standard Ocean should provide accurate, realistic, and seasonal (preferably monthly) surface-to-bottom profiles of the most probable sound speed, temperature, and salinity in each oceanic 1° × 1° square. The sound-speed profiles should be in a format suitable for numerical acoustic models and should accurately reproduce all acoustically significant features. The degree of oceanic variability in each square should be indicated whenever possible. Standard Ocean should also produce outputs that can be used to support the objective analysis of synoptic exercise environmental data.

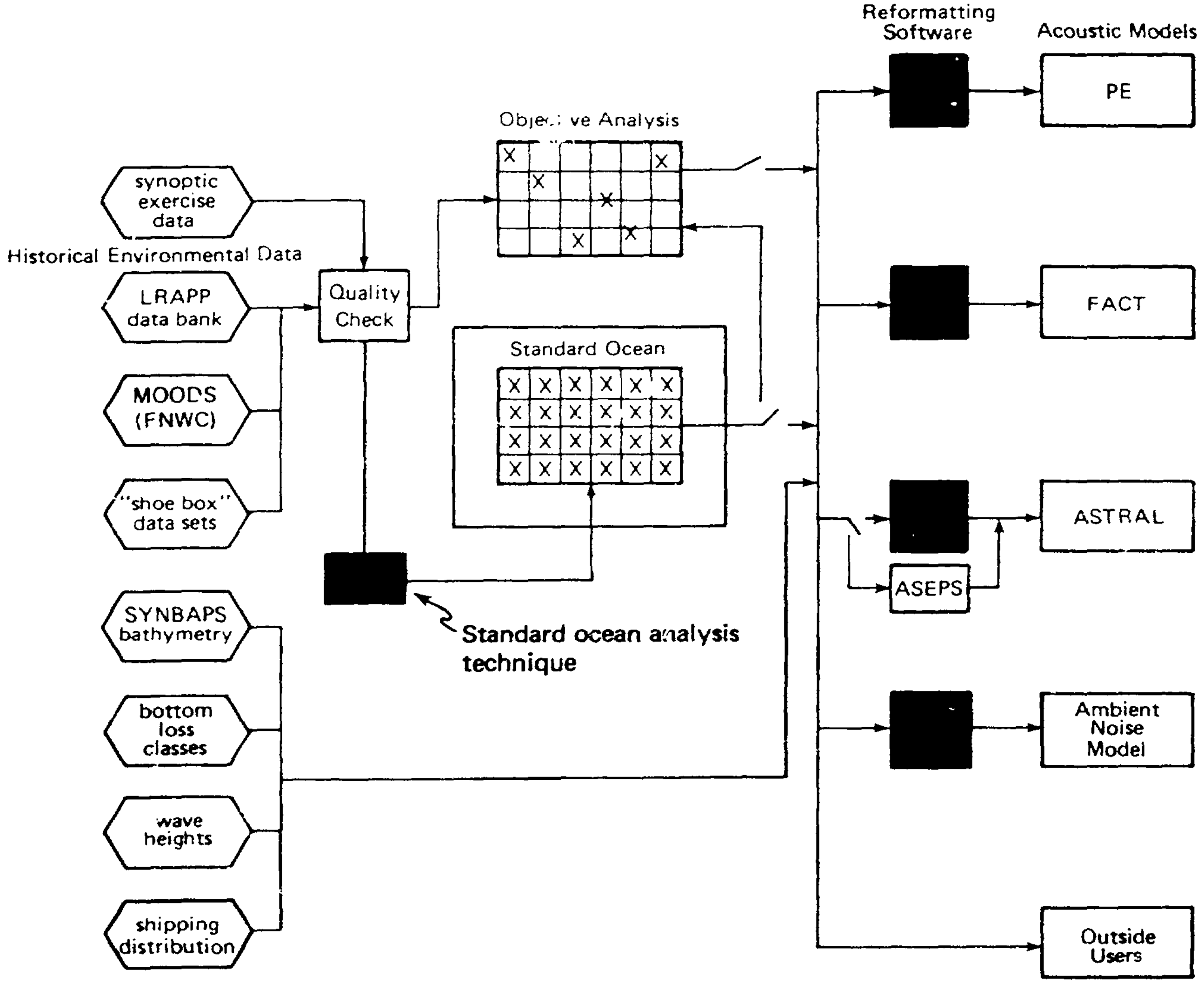

Fig. 1--Role of Standard Ocean in LRAPP data bank

- *Level of automation.* Standard Ocean's output should be easily usable by a nonspecialist.
- *Turnaround time and operating cost.* Standard Ocean should have minimal turnaround time and operating cost.
- *Time and cost to acquire.* Standard Ocean should be competitive in time and cost required to incorporate in the LRAPP data bank.

Section II presents the evaluation, which concludes with our findings on the candidates judged unsuitable or suitable for Standard Ocean. In Sec. III, we narrow the choice further and consider the tasks that remain before Standard Ocean can be installed.

II. EVALUATION

This section lists the eight Standard Ocean candidates we evaluated, describes their distinguishing characteristics, then explains why we find certain candidates unsuitable and others suitable for Standard Ocean.

THE CANDIDATES

The following list names the parent agency, key persons involved in each model's development and operation, and the appendix in this report that describes the system more fully.

- AUTO-OCEAN, in operation at NORDA, Code 320, NSTL Station, Bay St. Louis, Mississippi (Appendix A).
- FIB/EOTS/EXTRA (Fields by Information Blending/Extended Ocean Thermal Structure/EXTRAction), developed by Manfred Holl of Meteorology International, Inc., for FNWC, Monterey, California (Appendix B).
- GDEM (Generalized Digital Environmental Model), developed by Thomas M. Davis at NAVOCEANO, NSTL Station, Bay St. Louis, Mississippi (Appendix C).
- GFDL (no model name given), developed by Sydney Levitus and Abraham H. Oort of the Geophysical Fluid Dynamics Laboratory, NOAA at Princeton University, Princeton, New Jersey (Appendix D).
- HYDAT (HYdro-Climatological DATa Base), developed by Ocean Data Systems, Inc., Monterey, California, for FNWC; operated and modified by Evelyn A. Hesse, FNWC (Appendix E).
- ICAPS (Integrated Command Antisubmarine Warfare Prediction System), developed by Alvan Fisher, Jr. and operated by William R. Floyd and Paul Moersdorf of NAVOCEANO (Appendix F).
- ODSI (no model name given), proposed model to be developed by Capt. Paul M. Wolff of Ocean Data Systems, Inc. (Appendix G).

- SIMAS (Sonar In-Situ Mode Assessment System), developed by Eugene M. Podeszwa of NUSC, New London, Connecticut (Appendix H).

Distinguishing Characteristics

The candidates are differentiated by several key characteristics, summarized in Table 1. One is the method used to derive the model's output products. FIB/EOTS/EXTRA, GDEM, GFDL, and ICAPS use an objective analysis technique.* AUTO-OCEAN, HYDAT, and SIMAS store and retrieve typical observed profiles for each location and time period; in addition, AUTO-OCEAN performs some smoothing of typical profiles. ODSI's analysis technique is unclear.

The objective analysis approach has the advantage of working well in areas of sparse data, provided the surrounding areas have adequate data. Difficulty may arise in analyzing areas where all the data were collected over a short period or only during one or two seasons (seasonal aliasing). The objective analysis technique can also falter in analyzing situations where two or more water masses occupy a single square. If the masses have very distinct characteristics, the analysis may fall into the trap of producing an average result, which may never be found in reality.

The typical observed profile approach works well in areas with abundant observations, where it produces representative profiles close to the most probable real conditions. However, fewer than 3 million deep-ocean measurements have been taken worldwide,† and they cluster (1) along shipping lanes and around ocean weather stations in the northern hemisphere, and (2) in the warmer, less stormy months. When profiles are desired for the times and places unrepresented by data,

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*The objective analysis models vary in the sophistication and range of their techniques. The common thread is that their outputs are not observed profiles but profiles statistically derived from real data. Typically they are smoothed approximations of average or most probable oceanographic conditions and do not contain the "noise" found in real data. Locklin et al. review the objective analysis techniques of GDEM, FIB/EOTS/EXTRA, and GFDL.

†As opposed to surface measurements, of which there are about 30 million.

Table 1

DISTINGUISHING CHARACTERISTICS OF CANDIDATE MODELS

Characteristic	Model
Method of deriving outputs:	
Objective analysis	FIB/EOTS/EXTRA, GDEM, GFDL, ICAPS[a]
Typical observed profiles	AUTO-OCEAN, HYDAT, SIMAS[b]
Number of layers represented:	
One	HYDAT, ODSI
More than one	AUTO-OCEAN, FIB/EOTS/EXTRA, GDEM, GFDL,[c] ICAPS, SIMAS
Greatest depth of output products:	
≤ 5000 m	FIB/EOTS/EXTRA, GDEM (temperature and salinity only), GFDL
Bottom	AUTO-OCEAN, GDEM (sound speed only), HYDAT, ICAPS, SIMAS, ODSI

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[a] ICAPS uses a hybrid approach, combining XBT observations with an analyzed temperature profile after identifying the local water mass.

[b] Hand-smoothed.

[c] GFDL outputs 32 horizontally analyzed surfaces of temperature, salinity, sigma-T, and oxygen.

the skills of the oceanographer are strained and he may be forced to use "artistic license" in place of scientific techniques. Assuming that real data offer the most accurate standard, we evaluated the model outputs of GDEM by comparing them with typical observed profiles, particularly at locations where the data are plentiful (see Appendix C). Yet, to be effective worldwide, Standard Ocean may need to incorporate an objective analysis technique for use in sparsely sampled areas.

The second distinguishing characteristic is the number of layers used to represent variables such as temperature and salinity. ODSI and HYDAT use a single-layer model. The rest of the candidates are multilayer. The multilayer approach assumes that the water in the upper layers (typically <400 m) differs from deeper water in dynamic characteristics and time constants. AUTO-OCEAN, GDEM, FIB/EOTS/EXTRA, SIMAS, and ICAPS employ a two- or three-layer model. GFDL outputs horizontally analyzed surfaces at 32 depths of temperature, salinity, sigma-T, and oxygen. Unlike the other multilayer models, GFDL does not perform a vertical analysis, although the values at the different depths can be recombined to form vertical profiles. Using a multilayer model, the modeler can simultaneously represent the deeper ocean with an annual or winter-summer resolution and the upper layers with seasonal or monthly resolution. (ICAPS is an exception in this respect. It merges expendable bathythermograph (XBT) data with an appropriate deep (>200 m) temperature profile after determining the local water-mass characteristics--see Appendix F.) In the final output products the layers are merged over a range of depths around their overlap or meeting point. Another reason for the importance of temperature and salinity in Standard Ocean (besides the reasons given in Sec. I) is that errors are easier to detect in merges based on temperature and salinity than in merges based on sound speed alone.

The third distinguishing characteristic is the greatest depth to which the analysis extends. FIB/EOTS/EXTRA and GFDL produce output products no deeper than 5000 m. The rest extend to the bottom, except GDEM's temperature and salinity models, which do not extend beyond 800 m. The depth limitation does not exclude FIB/EOTS/EXTRA and GFDL from consideration, since their output could be extrapolated to the bottom with existing deep sound-speed data.*

Output Products

Table 2 summarizes the output products and coverage of the candidate models. The detail of the descriptions corresponds with the amount of information available. For example, much more information is available about GDEM than about HYDAT.

EVALUATION

Our evaluation of the candidate models against the requirements

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*J. J. Audet, Jr., *Seasonal Critical Depth Charts and Deep Sound Channel Interference for the Ocean and Seas of the Northern Hemisphere*, Acoustic Environmental Support Detachment, ONR, AESD Technical Note TN-75-02, April 1975.

Table 2

OUTPUT PRODUCTS AND COVERAGE OF CANDIDATE MODELS

Model	Temperature	Salinity	Sound Speed	Other Products	Coverage
AUTO-OCEAN	None	None	Seasonal, 5° × 5°, surface to bottom (extended to bottom via RSVP)	Bathymetry (1° × 1°), significant wave heights (seasonal, 5° × 5°), bottom loss classes (1° × 1°)	Northern hemisphere
FIB/EOTS/EXTRA	Variable spatial and temporal grid, surface to 5000 m	None	Variable spatial and temporal grid, surface to 5000 m. Computed from archived salinity and analyzed temperature fields using EXTRA	$\Delta T/\Delta Z$ and $\Delta^2 T/\Delta Z^2$, both variable spatial and temporal grid, surface to 5000 m	Northern hemisphere, small areas of southern hemisphere
GDEM	Seasonal, 30' × 30', surface to ~ 400 m at standard depths	Annual, 30' × 30', surface to 800 m at standard depths	Spatial resolution, 30' × 30'. Temporal resolution (3 models): (1) seasonal, 0 - ~ 400 m, (2) 2 seasons, 200-2450 m, (3) annual, 2000 m-bottom	SYNBAPS, 30' × 30', bathymetry	Mediterranean, N. Pacific (first run completed); N. Atlantic (in preparation)
GFDL	Monthly, 1° × 1°, 32 depths to 5000 m	Monthly, 1° × 1°, 32 depths to 5000 m	None	Sigma-T and oxygen, both monthly 1° × 1°, 32 depths to 5000 m	Worldwide
HYDAT	Variable spatial and temporal grid, surface to bottom	Variable spatial and temporal grid, surface to bottom	None	--	Worldwide
ICAPS	(1) 0-200 m using XBT as input, (2) 200 m to bottom using archived temperature	None	Surface to bottom. Uses analyzed temperature plus archived salinity (adjusted above 200 m to maintain stability)	Propagation loss and acoustic eigen-rays (using FACT), identification of water masses	Northern hemisphere, Indian Ocean to 20°S
ODSI	Monthly, 1° × 1° or less	Monthly, 1° × 1° or less	Monthly, 1° × 1° or less	Sigma-T, index of ocean variability, mixed layer thickness	Worldwide
SIMAS	None	None	(1) Monthly, homogeneous provinces, upper 366 m, (2) annual, homogeneous provinces, 366 m to 2134 m, (3) annual, uniform over entire ocean basin, 2134 m to bottom	--	Atlantic, 63°N-10°S, Pacific, 63°N-10°S, Indian Ocean to 50°S

specified in Sec. I revealed that each candidate has unique capabilities meeting one or more of LRAPP's requirements; none meets all of them.

Unsuitable Candidates

FIB/EOTS/EXTRA is a documented system both undergoing testing and in operation at FNWC. It is used on a CDC 6500 to objectively analyze oceanic thermal structure with XBT observations as inputs. The outputs are "fields," or horizontally analyzed surfaces of temperature and its so-called first and second differences defined on FNWC's standard 63 × 63 grid covering the northern hemisphere (i.e., $\Delta T/\Delta Z$ and $\Delta^2 T/\Delta Z^2$). The fields are computed at 26 depths between the surface and 5000 m, with increased resolution near the bottom of the mixed layer. Spatial resolution of the 63 × 63 grid at 60°N is ~ 380 km. For limited geographic areas, a grid of higher resolution is available down to 1/8 the standard. The system accepts as inputs temperature profiles that are irregularly spaced in time and space. Sound speed is computed using analyzed temperature, archived salinity, and the FNWC program EXTRA. In regions lacking XBT observations, the model reverts to the archived climatology.

The disadvantages of FIB/EOTS/EXTRA are that (1) it analyzes temperature only, using indirect means to compute sound speed, (2) the analysis is sensitive to the sparsity of synoptic XBT observations, so it relies heavily on static climatology,[*] (3) the merge of the surface temperature analysis (0-400 m) with the deep climatology could produce unrealistic results, and (4) the analysis extends only to 5000 m (not a serious deficiency).

The advantage of FIB/EOTS/EXTRA is the ease with which its objective-analysis technique could be developed for Standard Ocean by (1) improving the spatial grid to at least 1° × 1°, (2) increasing the depth coverage to possibly 11,000 m, and (3) improving the input climatology and adding salinity as an output. It would be most effective to run FIB/EOTS/EXTRA at FNWC and transfer the outputs to the LRAPP

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[*] This problem could be alleviated by (1) increasing the observation period from the present 12 hr to approximately one month and (2) updating the climatology with FNWC's new Master Oceanographic Observation Data Set (MOODS) containing ~ 2.8 × 10^6 observations.

data bank for inclusion in Standard Ocean. The likely cost of such implementation is unknown.

GFDL is an objective-analysis model that produces horizontal fields of analyzed temperature, salinity, sigma-T, and oxygen in worldwide 1° × 1° squares. Temporal resolution is monthly. The data are output at 32 depths from the surface to 5000 m. GFDL's most serious flaw is its lack of attempt to preserve the vertical integrity of the output fields. Sound speed, not a direct output product, must be derived from the model's temperature and salinity outputs. As vertical integrity is not preserved in those parameters, the sonic layer depths and secondary channels in any derived sound-speed profile will be distorted. In addition, the model produces seasonal aliasing in squares lacking complete seasonal data. It would probably be difficult to modify the model for Standard Ocean application because the objective-analysis computer code is specific to the GFDL computer; the output data format may also be unique.

The main advantages of GFDL are that the initial analysis of the fields is complete, the coverage is worldwide, and the model is presumably available now.

HYDAT is a retrieval system for selecting the most representative observed temperature and salinity profiles in a given area (multiple of 1° × 1° squares). Coverage is worldwide at intervals of one or two months. Profiles extend from surface to bottom.

HYDAT is unsuitable because (1) its analysis does not attempt to preserve representative sonic layer depths, (2) it sometimes fails to differentiate between two water masses (e.g., when water masses are different at the surface but the same at 243 m, and when water-mass characteristics reverse between the surface and 243 m), and (3) it does not preserve the horizontal integrity of the output fields.

HYDAT's older data set of 750,000 observations is to be replaced in late 1979 by FNWC's new MOODS observation data set. Evelyn A. Hess, who is debugging and modifying HYDAT at FNWC, does not consider the model ready for release yet. As HYDAT is designed to operate with FNWC software, it may require modification to operate on the LRAPP data bank. Finally, an experienced operator is needed to run HYDAT.

The main advantages of HYDAT are its worldwide coverage and its ability to sometimes identify the presence of two water masses in an area and give their mean characteristics.

ICAPS is a shipboard system for predicting sonar performance based on XBT inputs, archived water-mass characteristics, and FACT model runs. ICAPS merges an observed XBT with an appropriate deep (>200 m) temperature profile by identifying the water mass in the upper 200 m. The temperature and annual salinity profiles are used to compute a sound-speed profile, which is fed into the FACT model to produce acoustic eigen-rays and propagation loss.

ICAPS is operational only in the northern hemisphere. It cannot predict what the range-dependent environmental field will be during a particular period; it requires real XBT data as inputs. Furthermore, it assumes a uniform ocean in the vicinity of the XBT observation. As a result, its analyses are less reliable near fronts and in highly variable areas.

The main advantages of ICAPS are that (1) it can perform a synoptic water-mass analysis using observed data, (2) it is automated to the extent that a nonoceanographer or nonacoustician can get good results from it, and (3) it is operational and available now.

ODSI is a proposed model, yet to be built, that will provide a variety of oceanographic data including monthly maximum, minimum, and "most probable" profiles of temperature, salinity, computed sound speed, and sigma-T from surface to bottom. The spatial grid will typically be 1° × 1° or less, depending on the local complexity. Coverage will be worldwide. The model will also provide information on the frequency of current and frontal boundaries within squares, strong currents, eddies, "shelf phenomena" (not explained), and mixed layer thickness.

ODSI's disadvantage is that it remains largely conceptual and untested. We have seen no outputs to date, and more information on the methodology will be needed for an accurate evaluation. The developer estimates that the analysis for the entire world could be completed in 18 months at a cost of ~ $180,000; smaller portions could be provided on a prorated basis. We are unsure of the accuracy of these estimates.

The main advantage of ODSI is the variety and abundance of data it promises to provide, although some data may not be directly appropriate to LRAPP's needs. It is the only model we have found that attempts to deal with ocean variability. The variable spatial grid will be an advantage in areas containing fronts and currents. The procedure for producing the profiles will attempt to preserve horizontal gradients and vertical curvature.

SIMAS is designed to provide deep sound-speed profiles (≥366 m) to extend an observed XBT-derived sound-speed profile to the bottom. The basic data files contain annual sound-speed profiles for 70 so-called homogeneous areas in the North Atlantic, 69 areas in the North Pacific, and 50 areas in the Indian Ocean. Spatial resolution for data selection is presumed to be 1° × 1°. In addition, monthly best-guess sound-speed profiles are available for the upper 366 m. The program and data are computerized for shipboard operation. Profiles are also available in atlas reference charts by area.

SIMAS is unsuitable because its use of homogeneous area profiles does not yield realistic horizontal gradients, so it cannot produce reliable inputs for range-dependent models. In its favor, the analysis is complete and published in atlas form. Its availability, acquisition cost, and time to implement are unknown.

Potentially Suitable Candidates

AUTO-OCEAN is a CDC 6000 series retrieval system for selecting environmental parameters suitable for input to NORDA's numerical acoustic models. The retrieval data include (1) the most representative observed seasonal sound-speed profile (originally produced by RSVP), by 5° × 5° squares, (2) bathymetry data from Scripps Institution of Oceanography, by 1° × 1° squares or tracks, (3) seasonal significant wave heights by 5° × 5° squares, and (4) FNWC and NAVOCEANO bottom loss classes by 1° × 1° squares. Coverage is for the northern hemisphere. Outputs are on great-circle tracks. Sound-speed profiles are extended to the bottom using the deep profile data contained in RSVP; those data are the average sound speeds in each 5° × 5° square at 1000 m intervals between 1000 m and 10,000 m.

The main advantage of AUTO-OCEAN is that its products describe parameters not included in any other model (items 2, 3, and 4 above); those parameters are required as inputs for numerical acoustic models.

AUTO-OCEAN also operates rapidly and inexpensively (e.g., a single season of parameters for a 50 nm track could be produced in ~ 4 sec at a cost of ~ 24 cents, government rate). LRAPP has paid for the model, and it is available now.

AUTO-OCEAN's 5° × 5° spatial resolution for the sound-speed model is too coarse, and the model lacks temperature and salinity data; however, representative sound-speed, temperature, and salinity profiles can easily be inserted on a 1° × 1° grid spacing.

GDEM is an objective-analysis program that produces fields of analyzed temperature, salinity, and sound speed on a 30' × 30' grid over various depth ranges.[*] Preliminary analysis has been completed for the North Pacific and Mediterranean and is beginning for the North Atlantic. The Indian Ocean segment is to be completed sometime in the future. Observational data are insufficient to run GDEM in the southern hemisphere.

The GDEM component for the upper layer models seasonal temperature between the surface and the merge depth (~ 400 m),[†] annual salinity between the surface and either 400 m in the Mediterranean or 800 m in the Pacific, and seasonal sound speed from the surface to the merge depth in both oceans. The sound speed is derived from the analyzed temperature and salinity fields.

Below the surface models of temperature, salinity, and sound speed, there is a middepth, two-season (winter-summer) sound-speed model from 200 m to 2450 m. It is being augmented in the North Atlantic by a middepth temperature and salinity model (see Appendix C, Attachment 3).

The lowest component is an annual sound-speed model extending from 2000 m to the bottom. There is no evidence that the developer intends to replace this model with a temperature or salinity model in the near future.

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[*] This model has received our most detailed scrutiny to date.

[†] Merge depth, a variable peculiar to each ocean basin, is the depth at which two adjacent layers of the model are merged. In the early 1979 version of the model for the North Pacific, for example, that depth was fixed for the entire basin at 400 m. We understand that the latest versions of the model adjust merge depth over the basin to fit the observed data.

Each GDEM component uses a different curve-fitting technique to obtain the best fit to the edited observed data. Bathymetry data for the North Pacific and Mediterranean are on a 30' × 30' grid.

Of all Standard Ocean candidates using objective-analysis techniques, GDEM comes closest to reproducing the significant features in vertical sound-speed profiles. Comparison of model profiles with typical observed profiles for the North Pacific showed that GDEM maintains horizontal continuity yet preserves frontal structure in some cases. It appears to work well in areas with sparse data except the southern hemisphere. The 30' × 30' grid spacing is the smallest of any model yet evaluated. Operation is rapid (~ 3 min to edit an entire tape for one season in the North Pacific) and reported to be simple.

Several problems need to be resolved before GDEM could become the Standard Ocean retrieval system. One is a tendency toward error in modeling the upper layers at the higher latitudes in the North Pacific. The developer has undertaken a redesign of that portion of the model and may already have solved the problem (see Appendix C, Attachment 3). A second problem is an inexplicable seasonal shift in the GDEM sound-speed profiles in the North Pacific near 30°N, 140°W, between 300 and 1500 m. We do not know whether the recent redesign will correct that discrepancy. Its acoustic significance, however, is expected to be minimal. The redesigned model will be tested in FY 1980. The developer expects GDEM to be fully operational by early FY 1981.

III. CONCLUSIONS

Of the eight original candidates for Standard Ocean, we judge that AUTO-OCEAN and GDEM show the most potential for meeting LRAPP's requirements, and in a timely and cost-effective manner. Both models are continually being evaluated and modified, though AUTO-OCEAN is available now. Because of GDEM's realistic and detailed representation of the oceanic vertical and horizontal structure, it is our first choice for Standard Ocean. If GDEM is not available for installation by early FY 1981, we recommend that AUTO-OCEAN be installed in the interim and updated using typical observed profiles, as mentioned in Sec. II. By mid-FY 1980, we will know whether GDEM will be available on schedule; then we can recommend an appropriate course of action to bring a Standard Ocean on-line by early FY 1981. When GDEM is approved and released, we recommend that its output be stored in the AUTO-OCEAN framework. The advantage is that AUTO-OCEAN is a data retrieval system known to work; it should not be too difficult to replace AUTO-OCEAN's outmoded sound-speed profiles with the new GDEM profiles. Storing GDEM output in the AUTO-OCEAN framework would enable the acoustic modeler to retrieve sound speed, bottom loss class, bathymetry, and wave height in a single model run instead of the two or three runs otherwise required.

The only LRAPP requirement no candidate meets is the one for ocean variability. We suggest that LRAPP sponsor a study of ocean variability to produce a detailed 1° × 1° variability index to be included in Standard Ocean. We do not expect that the index could be implemented in time for the initial installation of Standard Ocean in early FY 1981.

Appendix A

AUTO-OCEAN[*]

AUTO-OCEAN is a CDC 6000 series retrieval system of environmental parameters suitable for input in numerical acoustic models. It is operational at Eglin AFB and is accessed via a remote terminal at NORDA (Code 320). AUTO-OCEAN provides the following environmental information for the entire northern hemisphere: (1) bathymetry (Scripps Institution of Oceanography) per 1° square or track, (2) seasonal significant wave heights per 5° square, (3) bottom loss classes (FNWC 1-5 and NOO 1-9) per 1° square, and (4) seasonal vertical sound-speed profiles (using RSVP) per 5° square. The sound-speed profiles are the most representative observed for the given square and season. The profiles are extended to the bottom using RSVP's deep profile data, which are average sound-speed values for each 5° × 5° square at 1000 m intervals between 1000 m and 10,000 m.[†]

The environmental information is generated along a great-circle path given either an initial point (lat, lon), bearing, and maximum range, or two points (initial and final lat, lon). The parameters are retrieved at each point where the selected track intersects a 1° lat, lon grid on the earth's surface. The data sources are the NODC ocean station data file to 1972, FNWC and NAVOCEANO bottom loss classes, AESD interim wave height data bank, and the Scripps bathymetric data file.

Turnaround time for AUTO-OCEAN is typically 4 sec for a 50 nm track; cost is about 24 cents for one season. The system is available now. Its technical quality is acceptable for most acoustic model runs,

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[*] This appendix draws on information provided in a letter to Daubin from Hashimoto, 28 March 1979.

[†] See J. J. Audet, Jr., and C. E. Vega, *AESD Sound-Speed Profile Retrieval System (RSVP)*, Acoustic Environmental Support Detachment, ONR, AESD Technical Note TN-74-03, October 1974; and Audet, *Seasonal Critical Depth Charts*.

depending on application and purpose. LRAPP has already paid for the product, so it could be acquired at no cost.

If AUTO-OCEAN is to serve as an interim or permanent Standard Ocean, we recommend that the current 5°-square sound-speed profiles be replaced by representative 1°-square sound-speed, temperature, and salinity profiles that are compatible with the 1° bathymetry and 1° bottom-loss-class data files. Those profiles could be produced by selecting the most typical observed profiles[*] or by an objective analysis technique (e.g., GDEM--see Appendix C). Objective analysis might preserve the horizontal continuity of the field better than observed profiles.

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[*] For example, J. G. Colborn and J. D. Pugh, *A Procedure for Selection of Typical Sound Speed Profiles*, Naval Undersea Center, NUC TN 1006, May 1973.

Appendix B

FIB/EOTS/EXTRA[*]

The FIB/EOTS (Field by Information Blending/Extended Ocean Thermal Structure) retrieval system is used at Fleet Numerical Weather Central (FNWC) for predicting oceanic thermal structure. The system now operates on a CDC 6500 computer; FNWC will use a Cyber 175 in the future. FIB/EOTS/EXTRA, discussed below, is the FIB/EOTS version that produces sound-speed profiles.

ANALYSIS

FIB/EOTS accepts irregularly spaced (temporal and spatial) temperature profiles as input. Those single observations are subjectively weighted according to relative accuracy and interpolated to the nodes of FNWC's standard 63 × 63 grid of the northern hemisphere (see Fig. B.1). At 60°N, that grid has a spatial resolution of $\Delta x \sim \Delta y \sim 380$ km. For limited geographical areas, a higher resolution grid is available down to 1/8 the standard. Then, "fields," horizontally analyzed surfaces of temperature and its first and second derivatives, are fitted to the data values at the grid nodes. The fields are computed at 26 depths (including standard depths) between the surface and 5000 m, with increased resolution near the primary layer depth (i.e., the point of the largest vertical curvature in the temperature profile).

For regions where no observed data are available, FIB/EOTS substitutes archived climatology values. Though not limited to the XBT (T-4) data format, FIB/EOTS uses primarily XBT observations as input. On a typical day, 400 are received, most as fleet messages (20-30 temperature-depth pairs) rather than actual XBT traces. For an input of that size, the turnaround time is approximately 1/2 hr.[†]

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[*] This appendix draws on information provided in a letter to Daubin from Ryan, 2 April 1979.

[†] FIB objective methodology, the basis of FIB/EOTS, is further described in the attachment to this appendix.

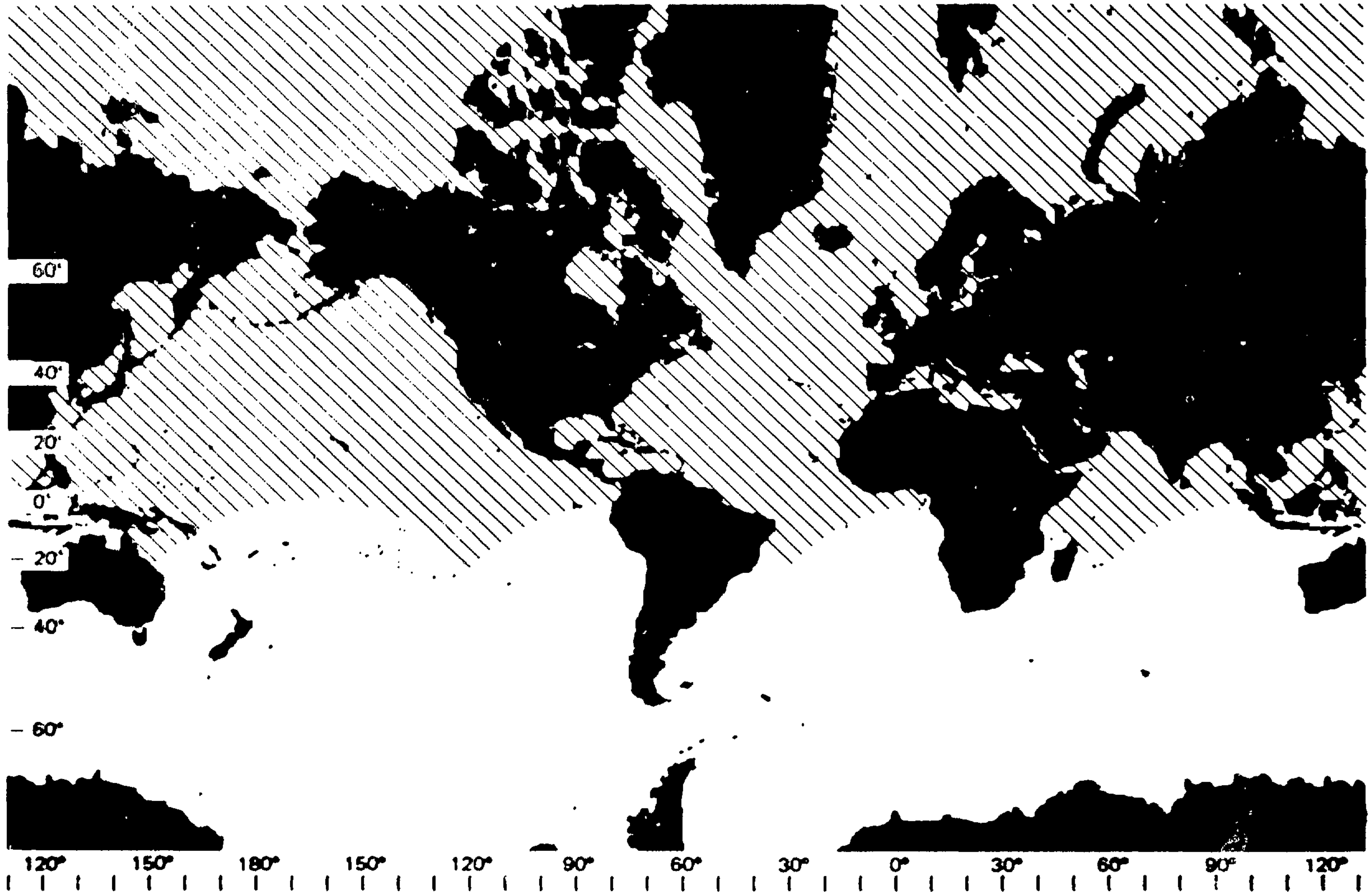

Fig. B.1--FNWC's standard 63 × 63 grid of the northern hemisphere

OUTPUT PRODUCTS

Temperature Profiles

Temperature profiles are computed at each grid node by merging the FIB-analyzed dynamic upper levels (≤400 m) with the static deeper level (>400 m) climatology in a way to minimize an error functional. The error functional is essentially a least-square minimization of the gradient and curvature of the computed profile. The merging process tends to shift the upper portion of the deeper level climatology toward the XBT observations near 400 m. Any climatological anomalies in the dynamic upper levels will be reflected in the profiles at greater depths. Because of the statistical nature of the FIB analysis, horizontal gradients will diminish unless the spatial data have been sampled adequately. However, the user can impose boundary conditions on the FIB analysis to retain certain gradient features.

Sound-Speed Profiles

The FNWC program EXTRA (EXTRAction) must be added to FIB/EOTS to produce sound-speed profiles. Using the FIB/EOTS temperature fields and *unanalyzed, archived* salinity data, EXTRA computes sound speed from Leroy's equations.* The program does not check the vertical stability of the computed temperature/salinity values at the grid nodes. Sound-speed profiles at points other than grid nodes are computed by linear interpolation between adjacent nodal values.

ADVANTAGES

FIB/EOTS has a number of positive qualities for oceanic temperature analysis:

- It is an operational program.
- Its documentation and source code are available.
- It is continuously being tested and evaluated.

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*C. C. Leroy, "Development of Simple Equations for Accurate and More Realistic Calculation of the Speed of Sound in Seawater," *J. Acoust. Soc. Am.*, Vol. 46, 1969, pp. 216-226.

- It is highly automated.
- The methodology is internally consistent.
- It has the capability of variable temporal resolution.
- It easily accepts new observations.
- Error estimates are made on the final output fields.
- It adequately preserves layer depth.
- It does not overburden computer resources.
- The FIB/EOTS/EXTRA objective analysis technique may be suitable for generating some Standard Ocean data sets.

DISADVANTAGES

For adaptation as Standard Ocean, FIB/EOTS/EXTRA has several weaknesses:

- The spatial resolution of the standard FNWC 63 × 63 grid is too coarse.
- Only temperature is analyzed; the salinity values are archived ones.
- The analysis is sensitive to the scarcity of synoptic XBT observations and thus relies heavily on static climatology.
- Vertical profile integrity is compromised by the merging of shallow ($\leq$400 m) synoptic XBT observations and deeper climatology.
- The climatology fields (temperature and salinity) used as inputs to the FIB analysis are of questionable suitability. (This weakness may be corrected when FNWC replaces the current climatology with the new and larger MOODS data set, as planned.)

Attachment

FIB OBJECTIVE ANALYSIS METHODOLOGY*

The Field of Information Blending (FIB) is a powerful analysis technique applicable to virtually any two-dimensional physical variable. As of 1973, FIB programs were being used at FNWC to analyze sea surface temperature and sea level pressure distributions. As of June 1975, an FIB adaptation for wind analysis (u, v) has been formulated and other applications are under development.

The FIB technique analyzes the distribution of a variable by blending measurements of the variable and its gradients, which come from different sources and locations. The program uses reports from various observation stations, with estimates of reliability, and it accepts regional or whole field estimates of the parameter and its derivatives (gradient, Laplacian, etc.). It checks all input data, rejects gross errors, and assembles the data. From this, it blends or analyzes to produce the optimum analysis which best fits all the information at hand. The technique also produces grid-point reliabilities of the final product. All input data are reevaluated individually by comparison with the blended analysis, which includes the interacting effects of all information that went into the analysis.

Reliability or weight is a measure of the worth of a piece of information. In every step of the FIB process, information exercises only the degree of influence warranted by its reliability value at that particular stage of the analysis. The ability to compute the information's reliability is the key to the FIB technique.

FIB has six component operations, to be discussed in the following sections.

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*This attachment is paraphrased from *U.S. Naval Weather Service Numerical Environmental Products Manual,* NAVAIR 50-1G-522, 1 June 1975, pp. 3.10-1 and 3.10-2. According to Jack Kaitala (FNWC), the description applies to the current FIB analysis.

FIRST-GUESS FIELD PREPARATION OF INITIALIZATION

The first guess is an estimate of what the analysis will be without considering current data. It provides continuity into data-sparse areas and gives an estimate of the shape (gradients, curvature, etc.) of the field. In sparse-data areas, the accuracy of the first analysis depends partly upon first-guess accuracy. The first guess is also useful for keeping "impossible" data from entering the analysis by indicating the approximate values expected in an area. Information is thus tested for credibility against the first guess.

The first guess in objective analysis models is either a previous analysis, extrapolated to analysis time, or a prognostic chart verified at analysis time.

FIB has the unique capability of accepting several first-guess fields, each weighted by its proportionate value. Later in the program, FIB can individually reevaluate the worth of each first-guess field. If a previous analysis is to be one of the first-guess fields, the FIB program has a special steering subroutine to bring the old analysis up to analysis time. In the sea-level pressure application, the 500-mb SR (residual) height field steers the previous analyses the appropriate distance and direction. This process, called kinematical extrapolation, gives a conservative first guess and is very informative when used with a more sophisticated, primitive-equation forecast.

ASSEMBLY OF NEW INFORMATION

Reports of the parameter being analyzed are placed at their proper geographical positions. The first-guess field value is interpolated at the report location, and the values are compared. In some analysis systems, only an arbitrarily assigned difference is allowed. If the allowed difference is exceeded, the report is thrown out. In the FIB method, the difference varies with the magnitude of the gradients near the report and, for some parameters, with latitude.

If the report passes the gross-error check, it is assigned a reliability or weight. This is based on the standard deviation of the errors associated with that type of report--the larger the standard deviation, the smaller the reliability. Other factors involved in determining the reliability vary with the parameter; examples include magnitude of the gradients near the report, age of the report, and station elevation.

The difference between the interpolated first-guess value and the report value is applied at the nearest grid point as a correction to the grid-point guess value. The total assembled value of the parameter at a grid point is a weighted mean of all the data referred to the grid point, with each value contributing to the mean in accordance with its reliability.

BLENDING FOR THE PARAMETER

Blending is the analysis stage, corresponding to the drawing of isolines by a hand analyst. The assembly step combined reports at their nearest grid points. The grid-point information is now spread to surrounding grid points by reference to previously derived gradients and higher order fields. The degree of spreading is increased with higher reliability in the gradient and other spreading fields.

After blending, each grid point will have a new parameter value, reflecting surrounding information as well as information at the grid point itself. This is an optimum compromise of all the weighted information.

RELIABILITY FIELD OF THE BLENDED PARAMETER

Next, a reliability field is computed for the blended parameter in preparation for the next step of reevaluation and error checking.

The blending process results in new parameter values at each grid point, and these values will have a different reliability or weight. For example, if one grid point had nothing but first-guess information before blending, its reliability would be much lower than surrounding grid points that have information from several observations. Blending spreads the information from the high-reliability grid points to the ones that have lower reliability. Blending increases reliability at all grid points, reflecting the additional information flowing in from surrounding grid points. Even the low-reliability points can add information to surrounding areas. The interaction between the grid points is greatest over a one-grid interval and diminishes with distance. The strength of interaction is limited by the gradient weight, i.e., if the gradient is known only slightly (low weight), even adjacent grid points will have little effect on each other.

REEVALUATION AND LATERAL REJECTION

FIB uses the blended parameter field and grid-point reliabilities to reevaluate each piece of information that entered into the analysis. The reevaluation provides quality measures for each observation and each first-guess field. The analysis cycle will be repeated using the reweighted information. The reevaluation stage is a vital and integral part of the FIB technique. This allows a second or even third analysis pass with ever-improving weights.

To reevaluate reports of any parameter, a statistical measure is computed for each report. This measure indicates the accuracy of a report compared with the accuracy expected from the designed reliability. Each report, with its weight, is individually removed from its grid point and compared with what remains, or the "background." If the report is within its expected error, no change is made in its reliability. If the error is greater than expected but within some upper limit, the report's reliability is reduced. If the error limit is exceeded, the report is rejected (i.e., its weight becomes zero) and it will have no effect when the next assembly and blending is made.

The reliability of the first-guess fields can be similarly evaluated. If new information disagrees with the first guess, the weight of the latter is reduced. In some applications involving rapid change, such as sea-level pressure, the first-guess weight is so small that reevaluation is not necessary.

REANALYSIS

The reanalysis begins by returning to the assembly stage. The new assembly starts with the first-guess fields, which may be reweighted, and the reports are assembled with their reevaluated weights. The whole cycle is repeated exactly as before. In the final pass (second or third analysis), the program skips the reevaluation and proceeds to the output section. The final analysis is stored in the computer for transmission and for input to other programs.

Appendix C

GDEM[*]

The Generalized Digital Environmental Model (GDEM) being developed by Thomas Davis of NAVOCEANO is an objective analysis program designed to produce seasonal fields of analyzed temperature, salinity, and sound speed on a 30' × 30' grid. The model's output can be adapted for use in an automated environmental data retrieval program to provide range-dependent inputs for acoustic modeling. GDEM is not yet operational, and the modeling processes are continually being evaluated and redeveloped. Therefore, little documentation is available,[†] and current descriptions must be regarded as tentative.

PRELIMINARY EVALUATION

To evaluate GDEM's ability to reproduce the typical vertical structure in selected oceanographic regions, NOSC selected real sound-speed profiles to represent six Northeast Pacific sound-speed provinces for the summer season and compared them with model outputs. We reported the results to LRAPP on 30 April 1979 (reproduced as Attachment 2). Some province profiles matched well, confirming GDEM's potential ability to reproduce real oceanographic vertical structure.

The results also uncovered a technical problem regarding the modeling of shallow-channel sound-speed structures observed around latitude 49°N. In some provinces the difference between the "typical" real and GDEM profiles exceeded the standard deviation for all real observations in the province at a number of depths. The greatest mismatches occurred

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[*] This appendix was written by Colborn, who also analyzed the NOSC comparison results.

[†] NAVOCEANO described the basic techniques of an early version of GDEM in an informal, unpublished report (reproduced as Attachment 1 to this appendix). A more detailed mathematical interpretation of the model, "LRAPP Objective Analysis," Ocean Data Systems, Inc., 20 March 1979, unpublished report, has been outdated by later model revisions.

at 250-500 m. In one instance, the model profile shifted the main channel axis to a depth outside the range of observed values near the test location.

Those discrepancies prompted NAVOCEANO to redesign portions of the model. At first the problem was thought to lie in the merging of the upper Butterworth filter model and the middepth orthogonal model. NAVOCEANO later found that replacing the quadratic tail in the upper-layer temperature model by an exponential function eliminated the shallow-channel discrepancies (see Attachment 3 for a recent memorandum reporting on the GDEM redesign).

RECENT EVALUATIONS

Vertical Structure

While awaiting the results of the model redesign, NOSC continued comparing data from the original model with North Pacific observations. The earlier comparisons used real profiles from an analysis defining sound-speed provinces. Those profiles were developed to represent a large region, whereas GDEM is designed to produce a profile representative of a single location. To match that design characteristic, we decided in the later comparisons to select real profiles representing point locations. Because a reasonable number of observations are required for selecting a typical profile, the data inventory was searched to locate 1° squares with high data density for evaluation. Figure C.1 shows the location of the six 1° squares selected. Locations 1, 2, 3, and 5 met the criterion of a reasonable number of observations for winter (January-March) and summer (July-September). Location 4 met the criterion only for the summer, and location 6 did not provide adequate data for either season.

Figures C.2 through C.13 graphically depict the comparisons between the selected typical profile for the specified 1° square and the GDEM profile for the central coordinates of the square. The maximum and minimum profile envelopes for all observed data are also plotted. Figures C.14 through C.25 overplot the GDEM profile on the composite plot for all deep observed profiles in each seasonal 1°-square data set.

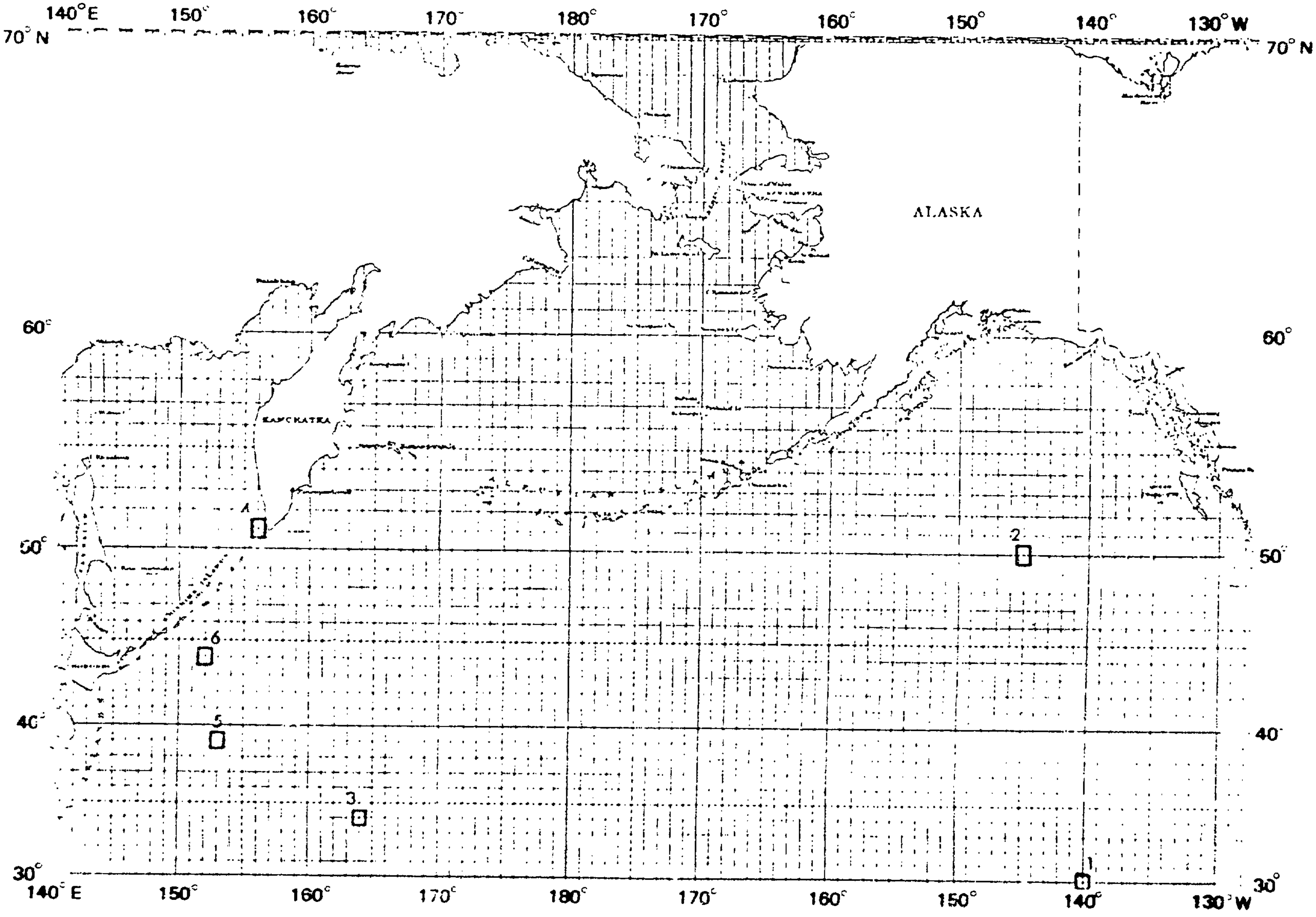
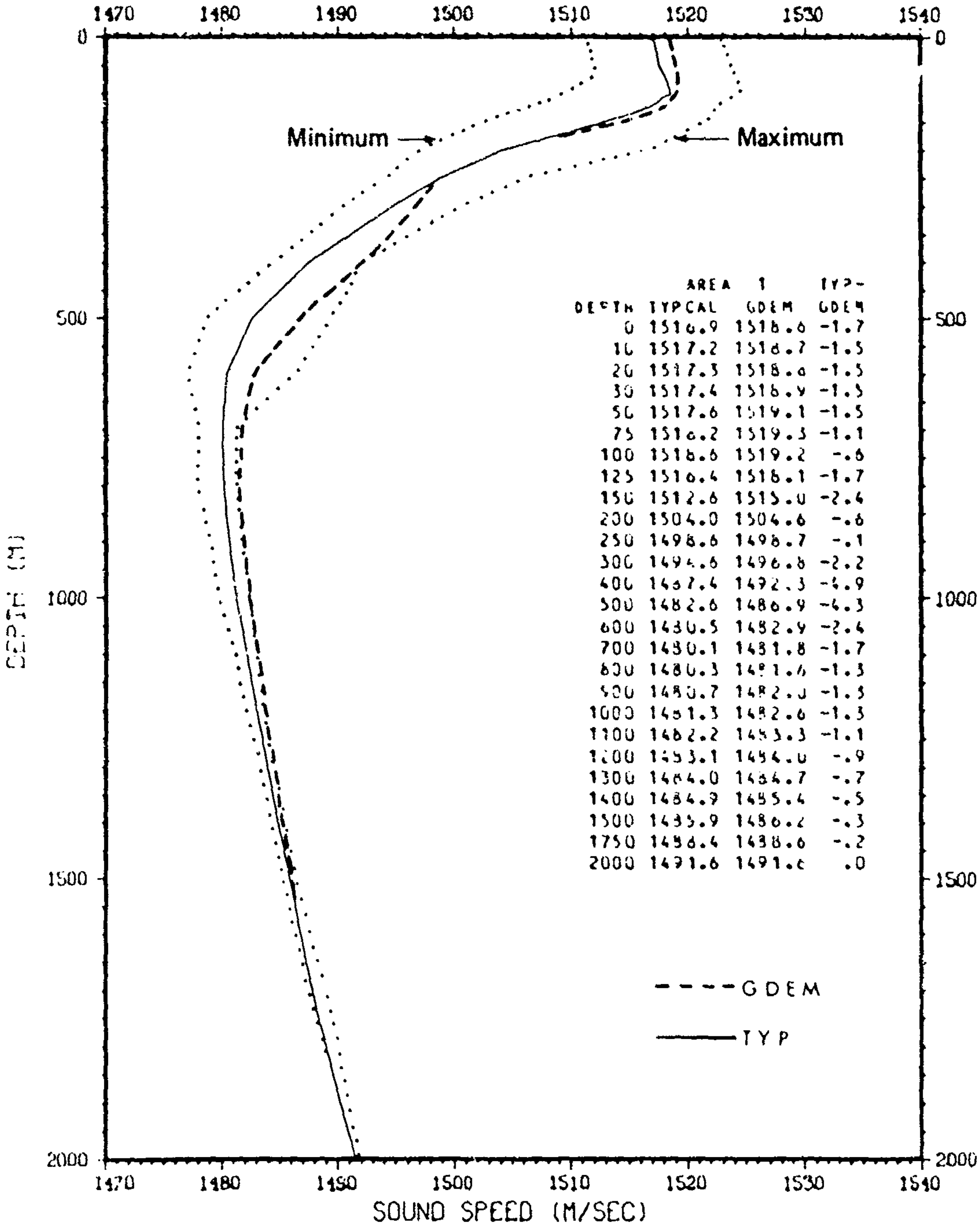
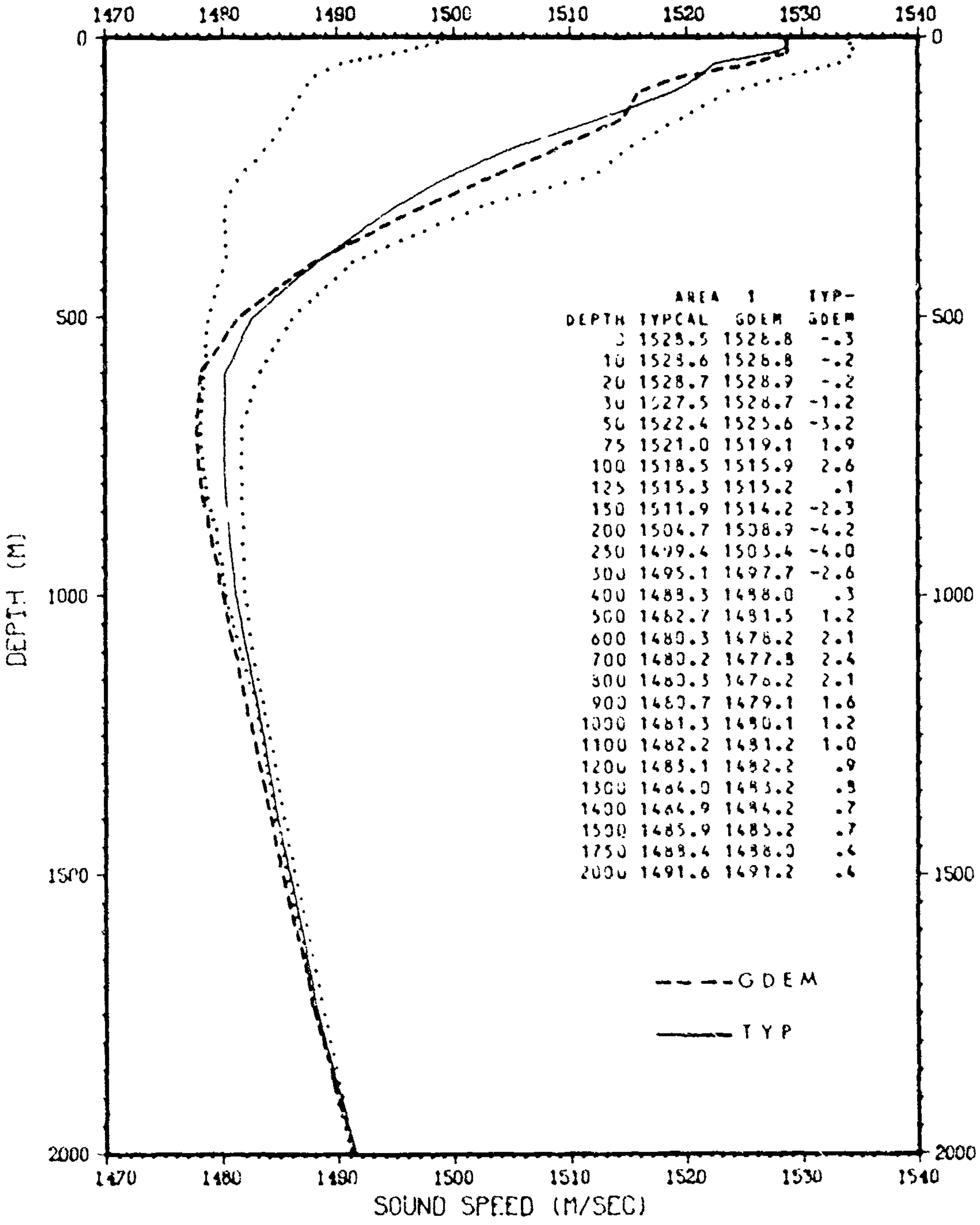


Fig. C.1--Locations of GDEM-typical observed profile comparisons



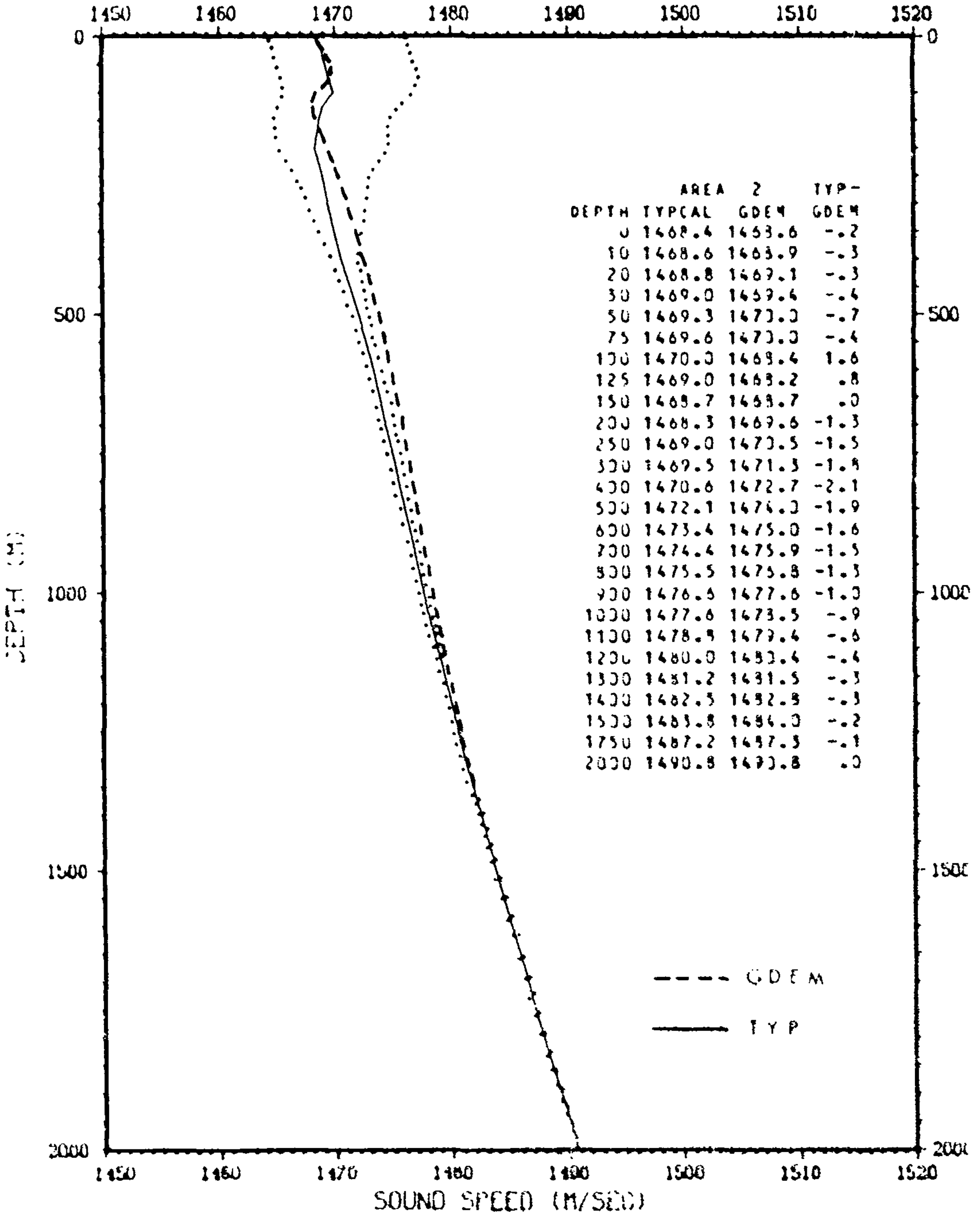
	AREA 1		TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1516.9	1518.6	-1.7
10	1517.2	1518.7	-1.5
20	1517.3	1518.8	-1.5
30	1517.4	1518.9	-1.5
50	1517.6	1519.1	-1.5
75	1518.2	1519.3	-1.1
100	1518.6	1519.2	-.6
125	1516.4	1518.1	-1.7
150	1512.6	1515.0	-2.4
200	1504.0	1504.6	-.6
250	1498.6	1498.7	-.1
300	1494.6	1496.8	-2.2
400	1487.4	1492.3	-4.9
500	1482.6	1486.9	-4.3
600	1480.5	1482.9	-2.4
700	1480.1	1481.8	-1.7
800	1480.3	1481.6	-1.3
900	1480.7	1482.0	-1.3
1000	1481.3	1482.6	-1.3
1100	1482.2	1483.3	-1.1
1200	1483.1	1484.0	-.9
1300	1484.0	1484.7	-.7
1400	1484.9	1485.4	-.5
1500	1485.9	1486.2	-.3
1750	1488.4	1488.6	-.2
2000	1491.6	1491.6	.0

Fig. C.2--GDEM-typical comparison, location 1 (30°N, 140°W), winter



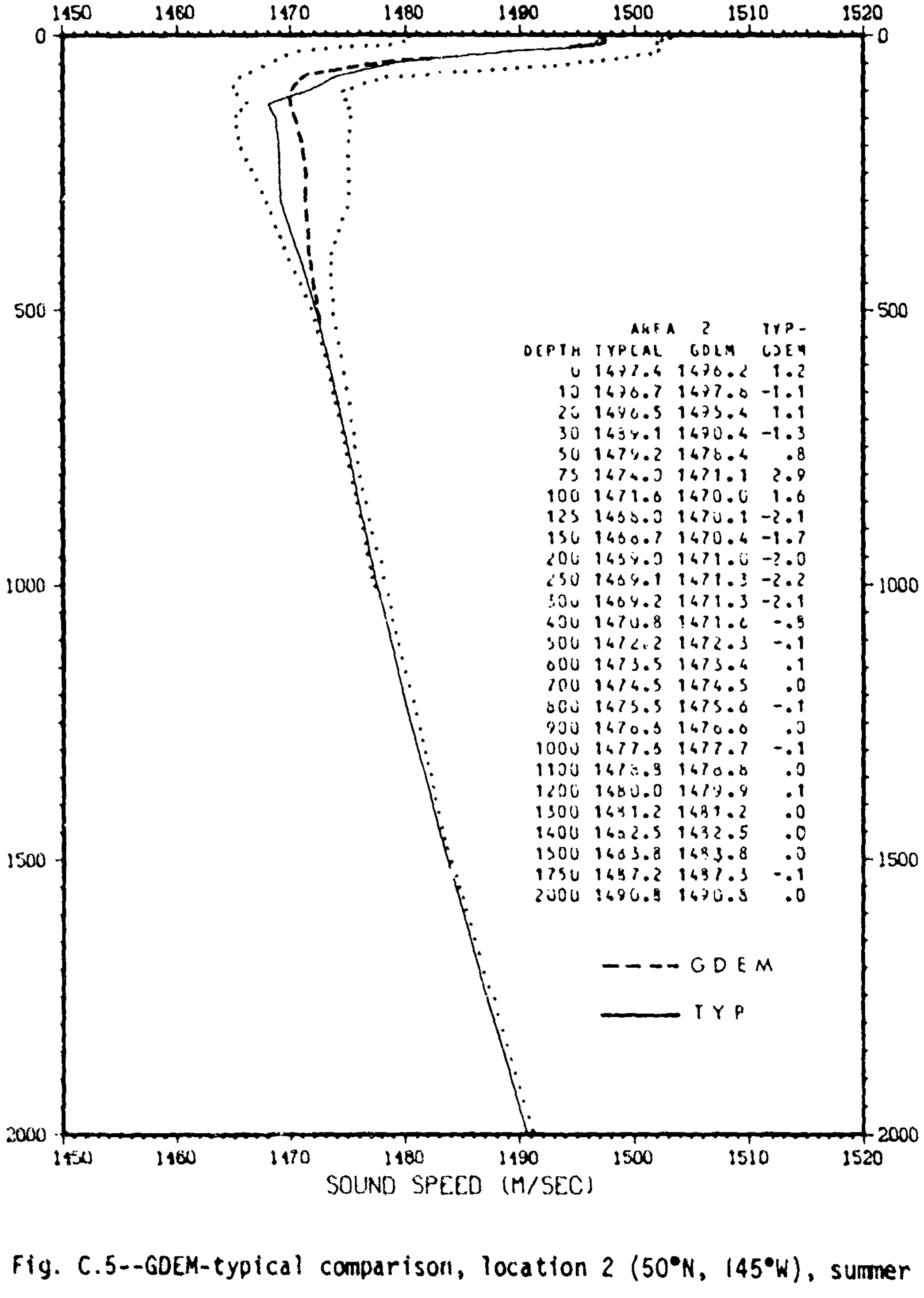
DEPTH	AREA 1 TYPCAL	GDEM	TYP- GDEM
0	1528.5	1528.8	-.3
10	1528.6	1528.8	-.2
20	1528.7	1528.9	-.2
30	1527.5	1528.7	-1.2
50	1522.4	1525.6	-3.2
75	1521.0	1519.1	1.9
100	1518.5	1515.9	2.6
125	1515.3	1515.2	.1
150	1511.9	1514.2	-2.3
200	1504.7	1508.9	-4.2
250	1499.4	1503.4	-4.0
300	1495.1	1497.7	-2.6
400	1488.3	1488.0	.3
500	1482.7	1481.5	1.2
600	1480.3	1478.2	2.1
700	1480.2	1477.8	2.4
800	1480.3	1478.2	2.1
900	1480.7	1479.1	1.6
1000	1481.3	1480.1	1.2
1100	1482.2	1481.2	1.0
1200	1483.1	1482.2	.9
1300	1484.0	1483.2	.8
1400	1484.9	1484.2	.7
1500	1485.9	1485.2	.7
1750	1488.4	1488.0	.4
2000	1491.6	1491.2	.4

Fig. C.3--GDEM-typical comparison, location 1 (30°N, 140°W), summer



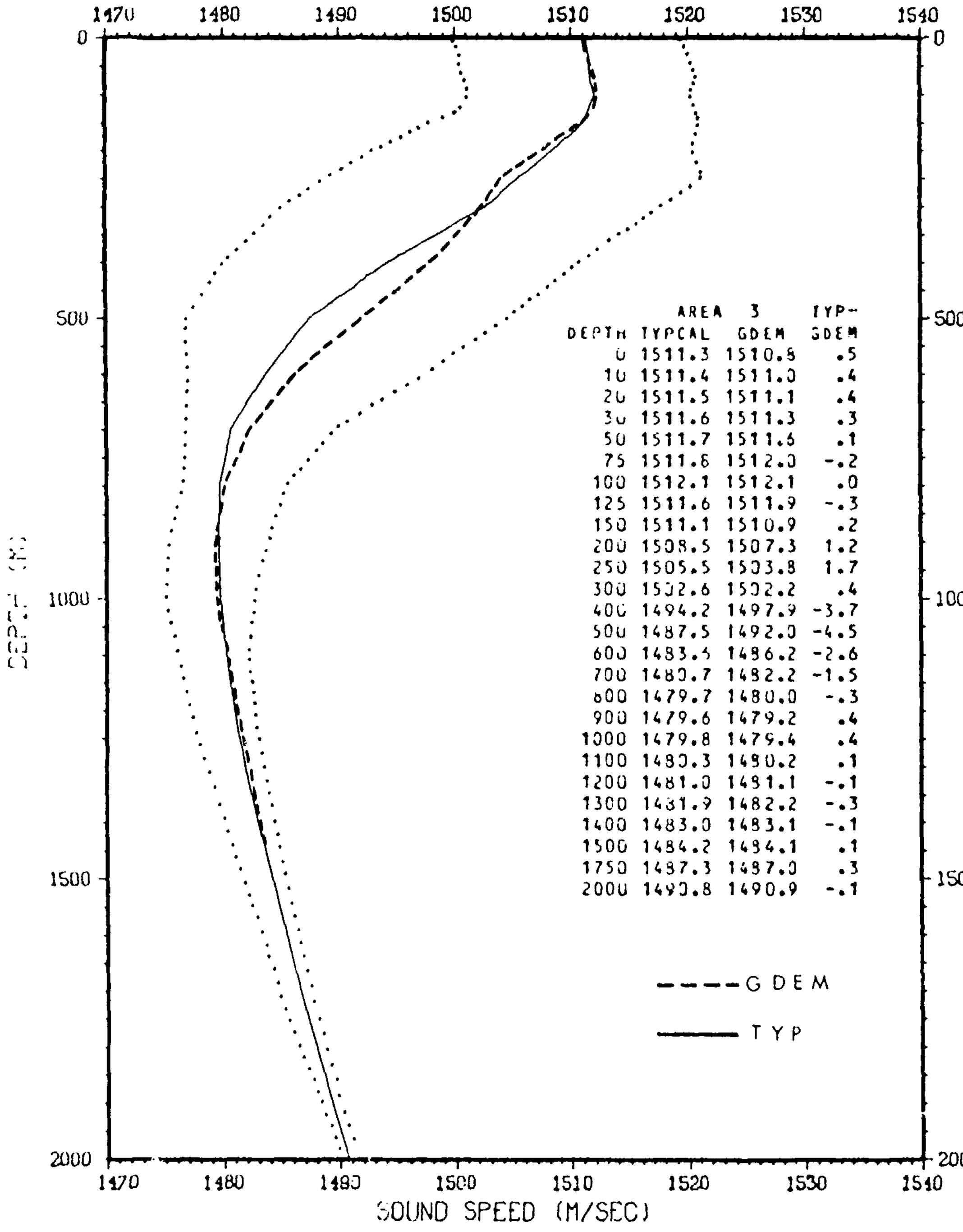
DEPTH	AREA 2 TYPCAL	AREA 2 GDEM	TYP-GDEM
0	1468.4	1468.6	-.2
10	1468.6	1468.9	-.3
20	1468.8	1469.1	-.3
30	1469.0	1469.4	-.4
50	1469.3	1470.0	-.7
75	1469.6	1470.0	-.4
100	1470.0	1468.4	1.6
125	1469.0	1468.2	.8
150	1468.7	1468.7	.0
200	1468.3	1469.6	-1.3
250	1469.0	1470.5	-1.5
300	1469.5	1471.3	-1.8
400	1470.6	1472.7	-2.1
500	1472.1	1474.0	-1.9
600	1473.4	1475.0	-1.6
700	1474.4	1475.9	-1.5
800	1475.5	1476.8	-1.3
900	1476.6	1477.6	-1.0
1000	1477.6	1478.5	-.9
1100	1478.8	1479.4	-.6
1200	1480.0	1480.4	-.4
1300	1481.2	1481.5	-.3
1400	1482.5	1482.8	-.3
1500	1483.8	1484.0	-.2
1750	1487.2	1487.3	-.1
2000	1490.8	1490.8	.0

Fig. C.4--GDEM-typical comparison, location 2 (50°N, 145°W), winter



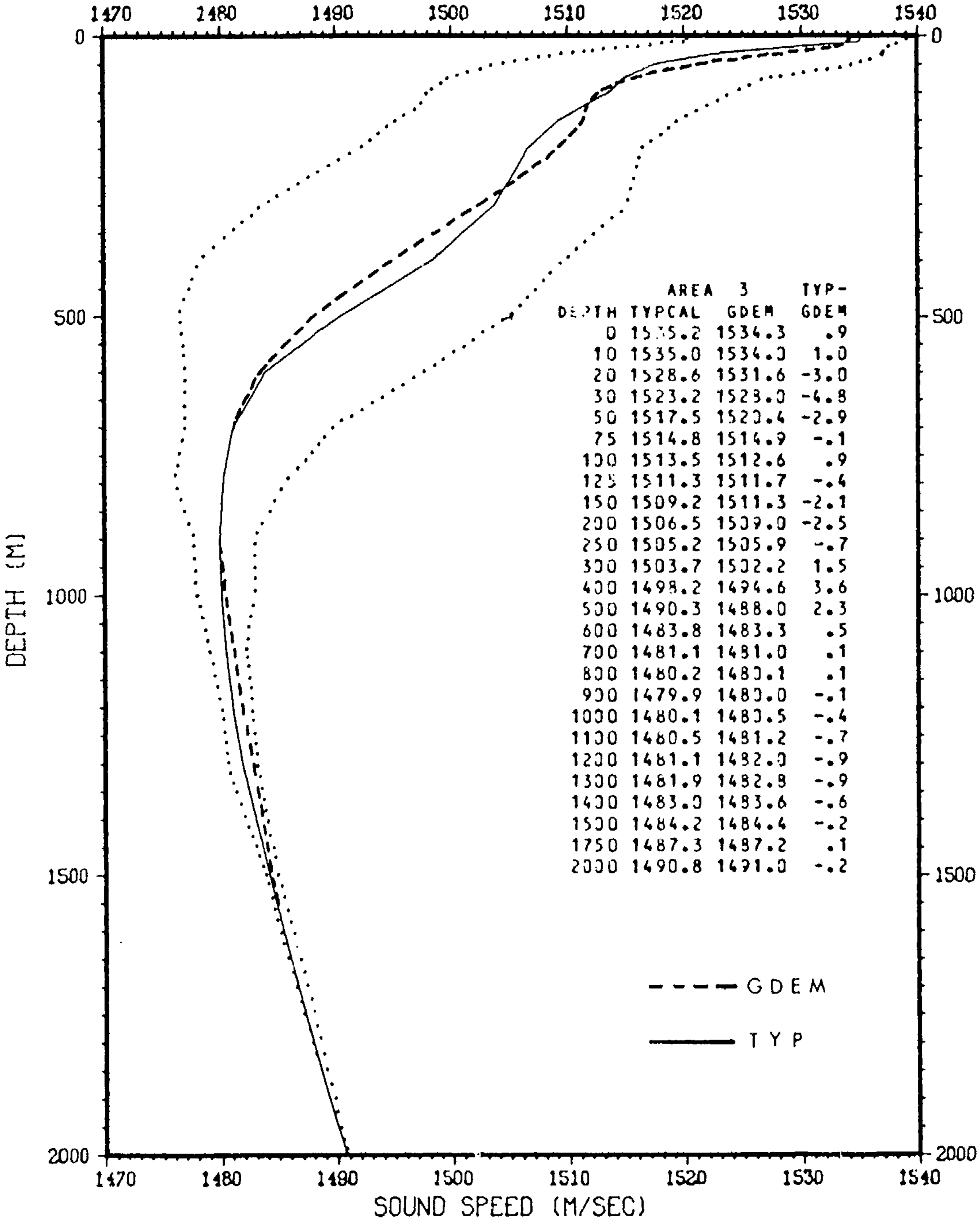
	AREA 2		TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1497.4	1496.2	1.2
10	1496.7	1497.8	-1.1
20	1496.5	1495.4	1.1
30	1489.1	1490.4	-1.3
50	1479.2	1478.4	.8
75	1474.0	1471.1	2.9
100	1471.6	1470.0	1.6
125	1468.0	1470.1	-2.1
150	1468.7	1470.4	-1.7
200	1469.0	1471.0	-2.0
250	1469.1	1471.3	-2.2
300	1469.2	1471.3	-2.1
400	1470.8	1471.6	-.8
500	1472.2	1472.3	-.1
600	1473.5	1473.4	.1
700	1474.5	1474.5	.0
800	1475.5	1475.6	-.1
900	1476.6	1476.6	.0
1000	1477.6	1477.7	-.1
1100	1478.8	1478.8	.0
1200	1480.0	1479.9	.1
1300	1481.2	1481.2	.0
1400	1482.5	1482.5	.0
1500	1483.8	1483.8	.0
1750	1487.2	1487.3	-.1
2000	1490.8	1490.8	.0

Fig. C.5--GDEM-typical comparison, location 2 (50°N, 145°W), summer



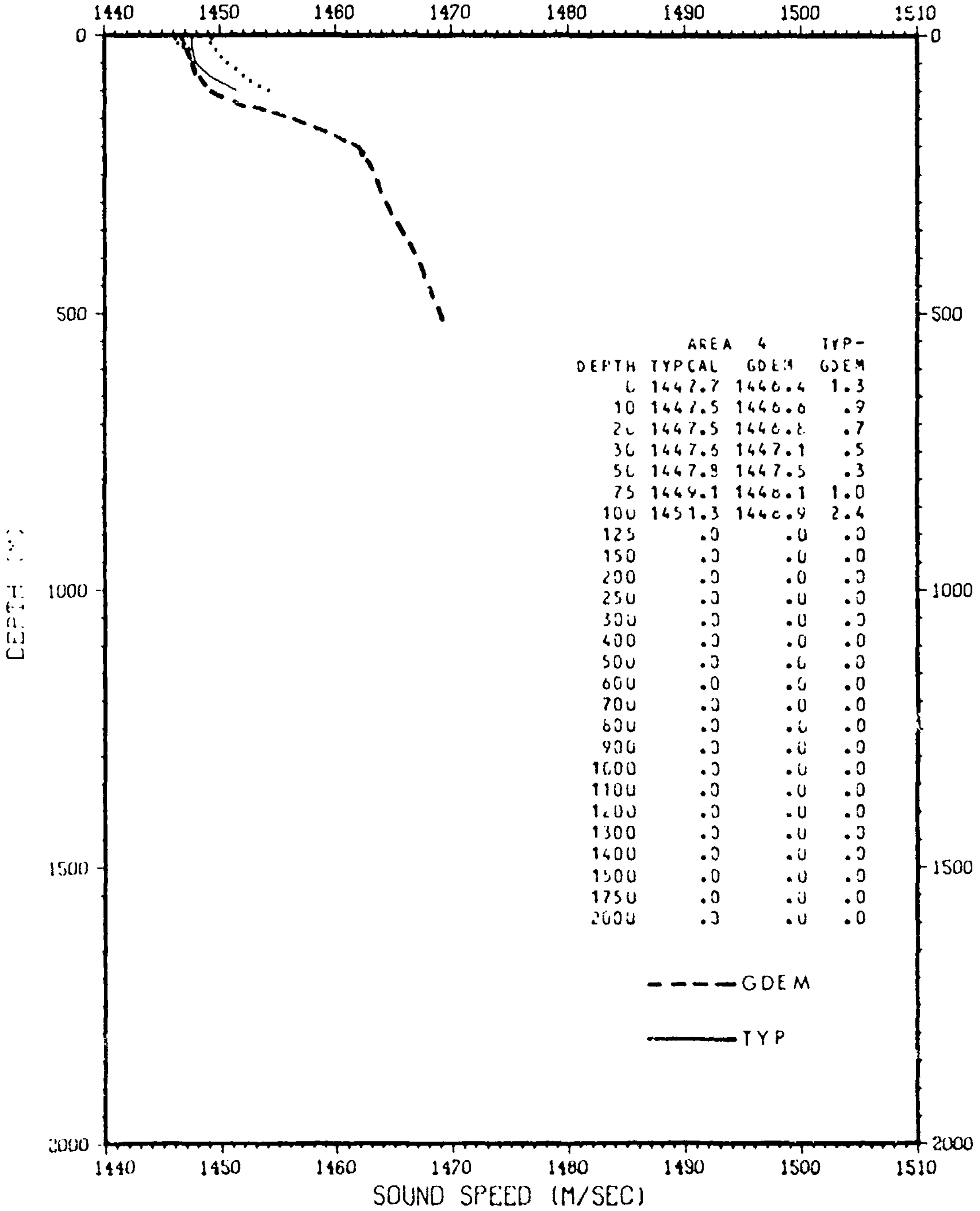
	AREA 3		TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1511.3	1510.8	.5
10	1511.4	1511.0	.4
20	1511.5	1511.1	.4
30	1511.6	1511.3	.3
50	1511.7	1511.6	.1
75	1511.8	1512.0	-.2
100	1512.1	1512.1	.0
125	1511.6	1511.9	-.3
150	1511.1	1510.9	.2
200	1508.5	1507.3	1.2
250	1505.5	1503.8	1.7
300	1502.6	1502.2	.4
400	1494.2	1497.9	-3.7
500	1487.5	1492.0	-4.5
600	1483.6	1486.2	-2.6
700	1480.7	1482.2	-1.5
800	1479.7	1480.0	-.3
900	1479.6	1479.2	.4
1000	1479.8	1479.4	.4
1100	1480.3	1480.2	.1
1200	1481.0	1481.1	-.1
1300	1481.9	1482.2	-.3
1400	1483.0	1483.1	-.1
1500	1484.2	1484.1	.1
1750	1487.3	1487.0	.3
2000	1490.8	1490.9	-.1

Fig. C.6--GDEM-typical comparison, location 3 (34°N, 164°E), winter



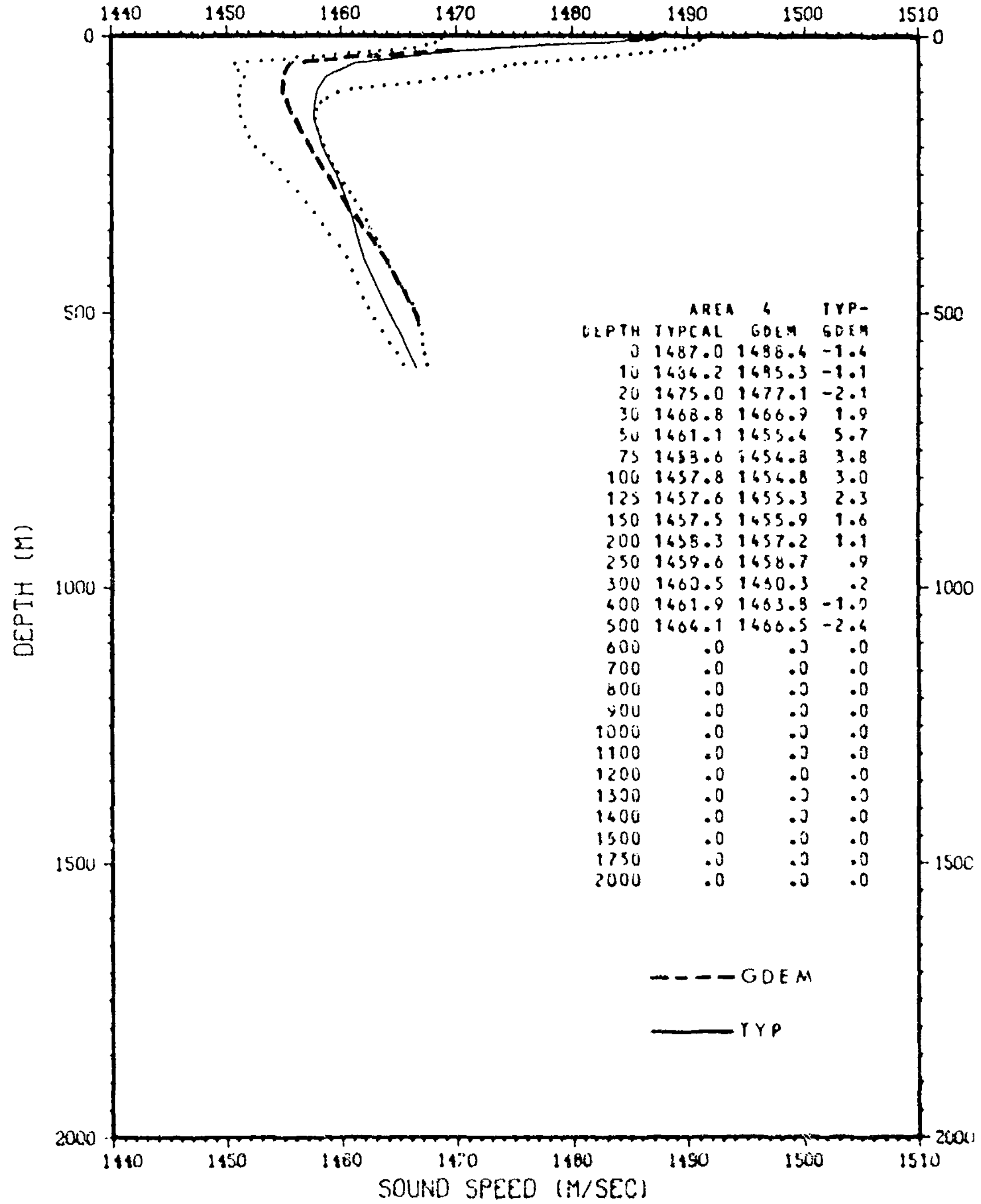
	AREA	3	TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1535.2	1534.3	.9
10	1535.0	1534.0	1.0
20	1528.6	1531.6	-3.0
30	1523.2	1528.0	-4.8
50	1517.5	1520.4	-2.9
75	1514.8	1514.9	-.1
100	1513.5	1512.6	.9
125	1511.3	1511.7	-.4
150	1509.2	1511.3	-2.1
200	1506.5	1509.0	-2.5
250	1505.2	1505.9	-.7
300	1503.7	1502.2	1.5
400	1498.2	1494.6	3.6
500	1490.3	1488.0	2.3
600	1483.8	1483.3	.5
700	1481.1	1481.0	.1
800	1480.2	1480.1	.1
900	1479.9	1480.0	-.1
1000	1480.1	1480.5	-.4
1100	1480.5	1481.2	-.7
1200	1481.1	1482.0	-.9
1300	1481.9	1482.8	-.9
1400	1483.0	1483.6	-.6
1500	1484.2	1484.4	-.2
1750	1487.3	1487.2	.1
2000	1490.8	1491.0	-.2

Fig. C.7--GDEM-typical comparison, location 3 (34°N, 164°E), summer



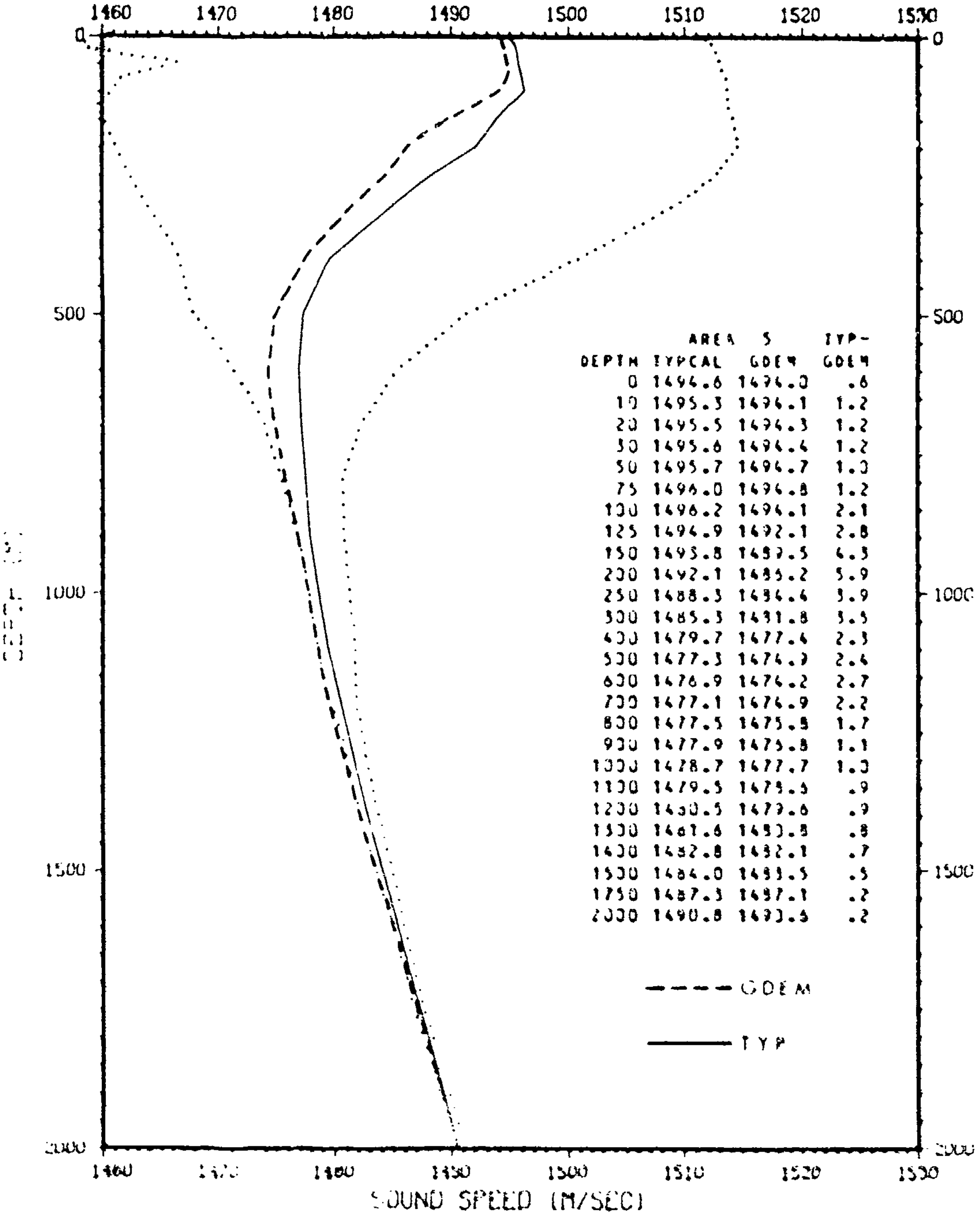
	AREA	4	TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1447.7	1446.4	1.3
10	1447.5	1446.6	.9
20	1447.5	1446.8	.7
30	1447.6	1447.1	.5
50	1447.8	1447.5	.3
75	1449.1	1448.1	1.0
100	1451.3	1448.9	2.4
125	.0	.0	.0
150	.0	.0	.0
200	.0	.0	.0
250	.0	.0	.0
300	.0	.0	.0
400	.0	.0	.0
500	.0	.0	.0
600	.0	.0	.0
700	.0	.0	.0
800	.0	.0	.0
900	.0	.0	.0
1000	.0	.0	.0
1100	.0	.0	.0
1200	.0	.0	.0
1300	.0	.0	.0
1400	.0	.0	.0
1500	.0	.0	.0
1750	.0	.0	.0
2000	.0	.0	.0

Fig. C.8--GDEM-typical comparison, location 4 (51°N, 156°E), winter



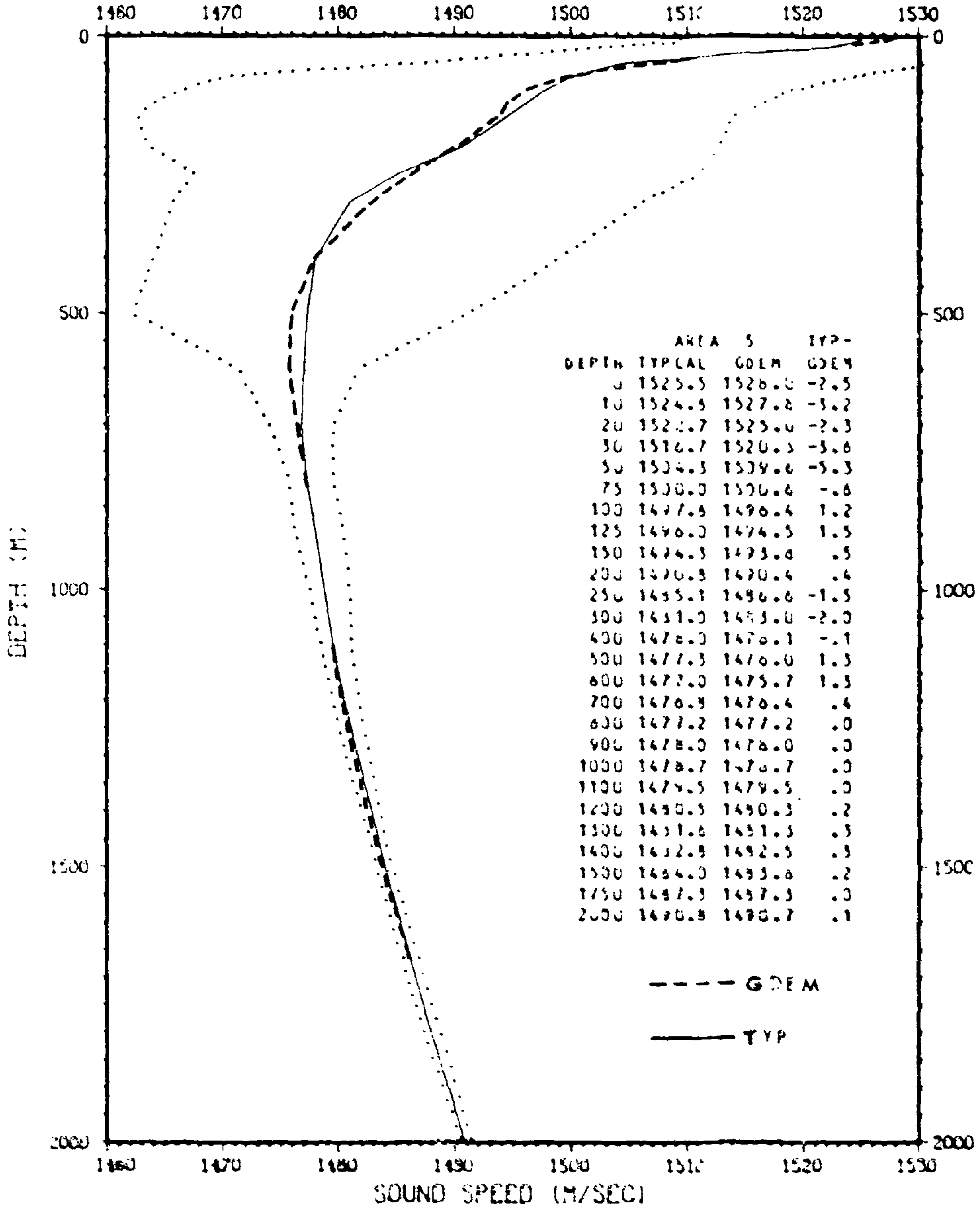
	AREA	4	TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1487.0	1488.4	-1.4
10	1484.2	1485.3	-1.1
20	1475.0	1477.1	-2.1
30	1468.8	1466.9	1.9
50	1461.1	1455.4	5.7
75	1458.6	1454.8	3.8
100	1457.8	1454.8	3.0
125	1457.6	1455.3	2.3
150	1457.5	1455.9	1.6
200	1458.3	1457.2	1.1
250	1459.6	1458.7	.9
300	1460.5	1460.3	.2
400	1461.9	1463.8	-1.9
500	1464.1	1466.5	-2.4
600	.0	.0	.0
700	.0	.0	.0
800	.0	.0	.0
900	.0	.0	.0
1000	.0	.0	.0
1100	.0	.0	.0
1200	.0	.0	.0
1300	.0	.0	.0
1400	.0	.0	.0
1500	.0	.0	.0
1750	.0	.0	.0
2000	.0	.0	.0

Fig. C.9--GDEM-typical comparison, location 4 (51°N, 156°E), summer



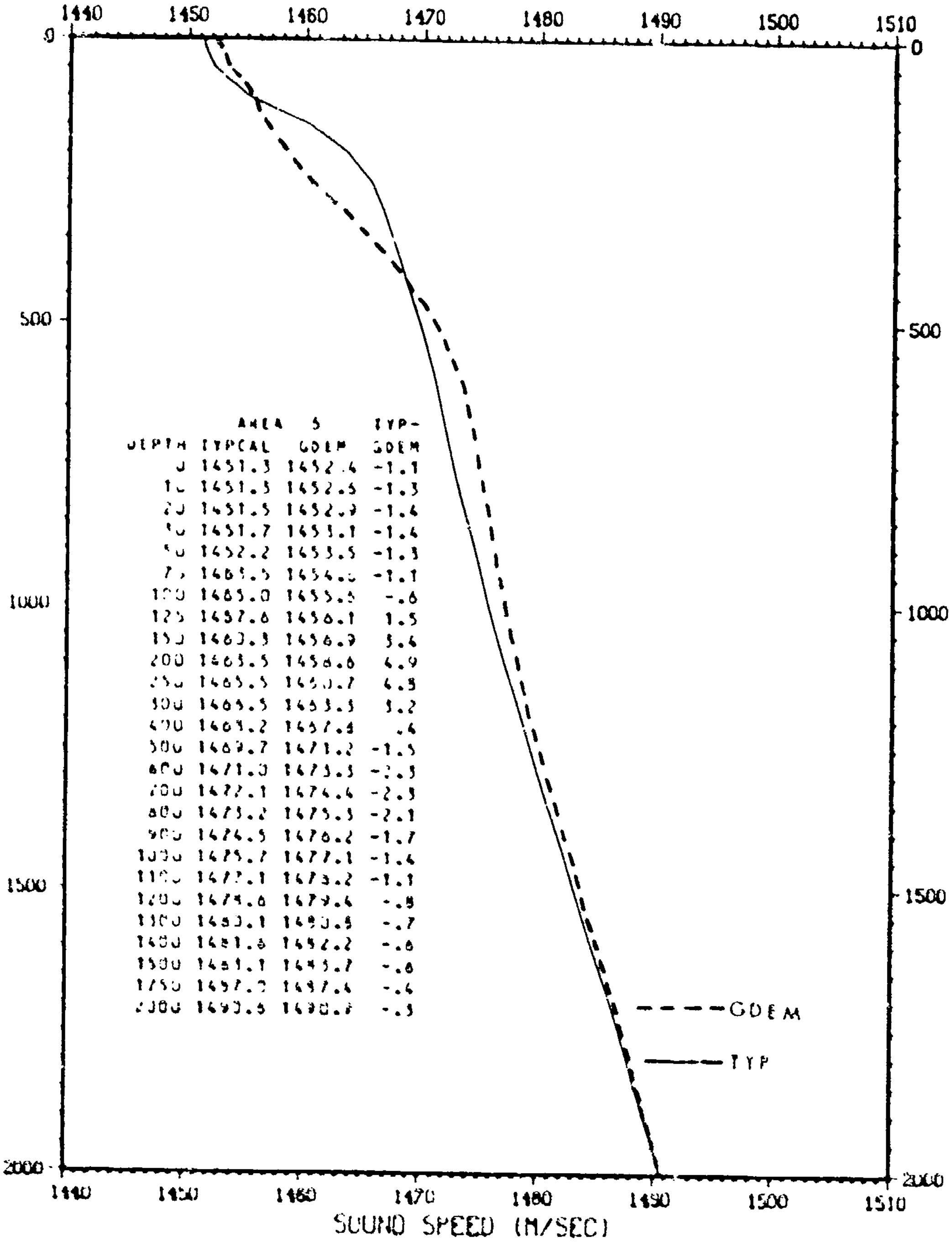
	AREA 5		TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1494.6	1494.0	.6
10	1495.3	1494.1	1.2
20	1495.5	1494.3	1.2
30	1495.6	1494.4	1.2
50	1495.7	1494.7	1.0
75	1496.0	1494.8	1.2
100	1496.2	1494.1	2.1
125	1494.9	1492.1	2.8
150	1493.8	1489.5	4.3
200	1492.1	1486.2	5.9
250	1488.3	1484.4	3.9
300	1485.3	1481.8	3.5
400	1479.7	1477.4	2.3
500	1477.3	1474.9	2.4
600	1476.9	1474.2	2.7
700	1477.1	1474.9	2.2
800	1477.5	1475.8	1.7
900	1477.9	1476.8	1.1
1000	1478.7	1477.7	1.0
1100	1479.5	1478.6	.9
1200	1480.5	1479.6	.9
1300	1481.6	1480.8	.8
1400	1482.8	1482.1	.7
1500	1484.0	1483.5	.5
1750	1487.3	1487.1	.2
2000	1490.8	1490.6	.2

Fig. C.10--GDEM-typical comparison, location 5 (39°N, 153°E), winter



	AREA	5	TYP-
DEPTH	TYPICAL	GDEM	GDEM
0	1525.5	1528.0	-2.5
10	1524.6	1527.8	-3.2
20	1522.7	1525.0	-2.3
30	1516.7	1520.3	-3.6
50	1504.3	1509.6	-5.3
75	1500.0	1500.6	-.6
100	1497.6	1496.4	1.2
125	1496.0	1494.5	1.5
150	1494.3	1493.8	.5
200	1490.8	1490.4	.4
250	1485.1	1486.6	-1.5
300	1481.0	1483.0	-2.0
400	1478.0	1478.1	-.1
500	1477.3	1476.0	1.3
600	1477.0	1475.7	1.3
700	1476.8	1476.4	.4
800	1477.2	1477.2	.0
900	1478.0	1478.0	.0
1000	1478.7	1478.7	.0
1100	1479.5	1479.5	.0
1200	1480.5	1480.3	.2
1300	1481.6	1481.3	.3
1400	1482.8	1482.5	.3
1500	1484.0	1483.8	.2
1750	1487.3	1487.3	.0
2000	1490.8	1490.7	.1

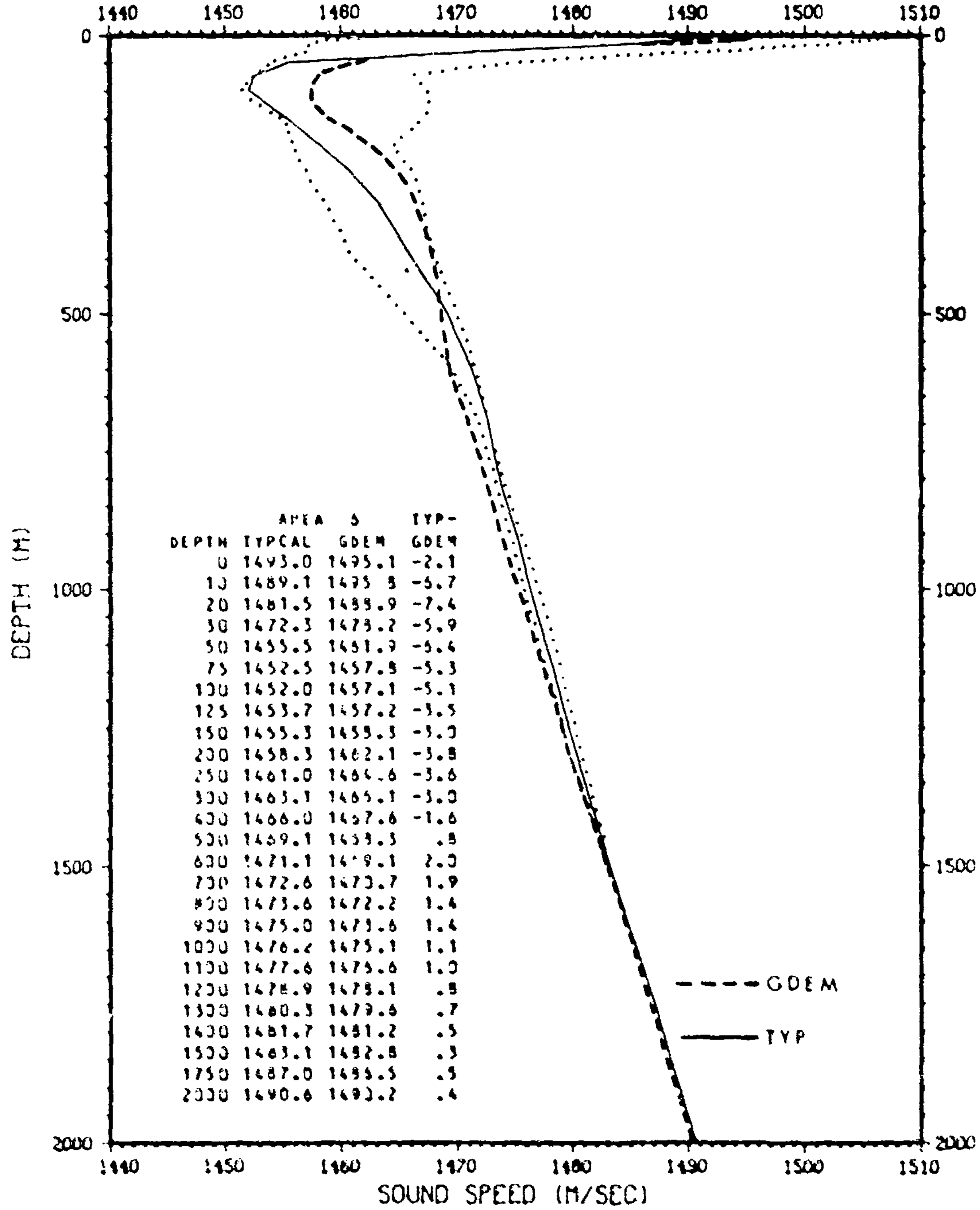
Fig. C.11--GDEM-typical comparison, location 5 (39°N, 153°E), summer



AREA 5

DEPTH	TYPCAL	GDEM	TYP-GDEM
0	1451.3	1452.4	-1.1
10	1451.3	1452.6	-1.3
20	1451.5	1452.9	-1.4
30	1451.7	1453.1	-1.4
50	1452.2	1453.5	-1.3
75	1453.5	1454.6	-1.1
100	1455.0	1455.6	-.6
125	1457.6	1456.1	1.5
150	1460.3	1456.9	3.4
200	1463.5	1458.6	4.9
250	1465.5	1460.7	4.8
300	1466.5	1463.3	3.2
400	1468.2	1467.8	.4
500	1469.7	1471.2	-1.5
600	1471.0	1473.3	-2.3
700	1472.1	1474.4	-2.3
800	1473.2	1475.3	-2.1
900	1474.5	1476.2	-1.7
1000	1475.7	1477.1	-1.4
1100	1477.1	1478.2	-1.1
1200	1478.6	1479.4	-.8
1300	1480.1	1480.8	-.7
1400	1481.6	1482.2	-.6
1500	1483.1	1483.7	-.6
1750	1487.0	1487.4	-.4
2000	1490.5	1490.8	-.3

Fig. C.12--GDEM-typical comparison, location 6 (44°N, 152°E), winter



	AREA 5		TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1493.0	1495.1	-2.1
10	1489.1	1495.8	-6.7
20	1481.5	1488.9	-7.4
30	1472.3	1478.2	-5.9
50	1455.5	1461.9	-6.4
75	1452.5	1457.8	-5.3
100	1452.0	1457.1	-5.1
125	1453.7	1457.2	-3.5
150	1455.3	1458.3	-3.0
200	1458.3	1462.1	-3.8
250	1461.0	1464.6	-3.6
300	1463.1	1466.1	-3.0
400	1466.0	1467.6	-1.6
500	1469.1	1468.3	.8
600	1471.1	1469.1	2.0
700	1472.6	1470.7	1.9
800	1473.6	1472.2	1.4
900	1475.0	1473.6	1.4
1000	1476.2	1475.1	1.1
1100	1477.6	1476.6	1.0
1200	1478.9	1478.1	.8
1300	1480.3	1479.6	.7
1400	1481.7	1481.2	.5
1500	1483.1	1482.8	.3
1750	1487.0	1486.5	.5
2000	1490.6	1490.2	.4

Fig. C.13--GDEM-typical comparison, location 6 (44°N, 152°E), summer

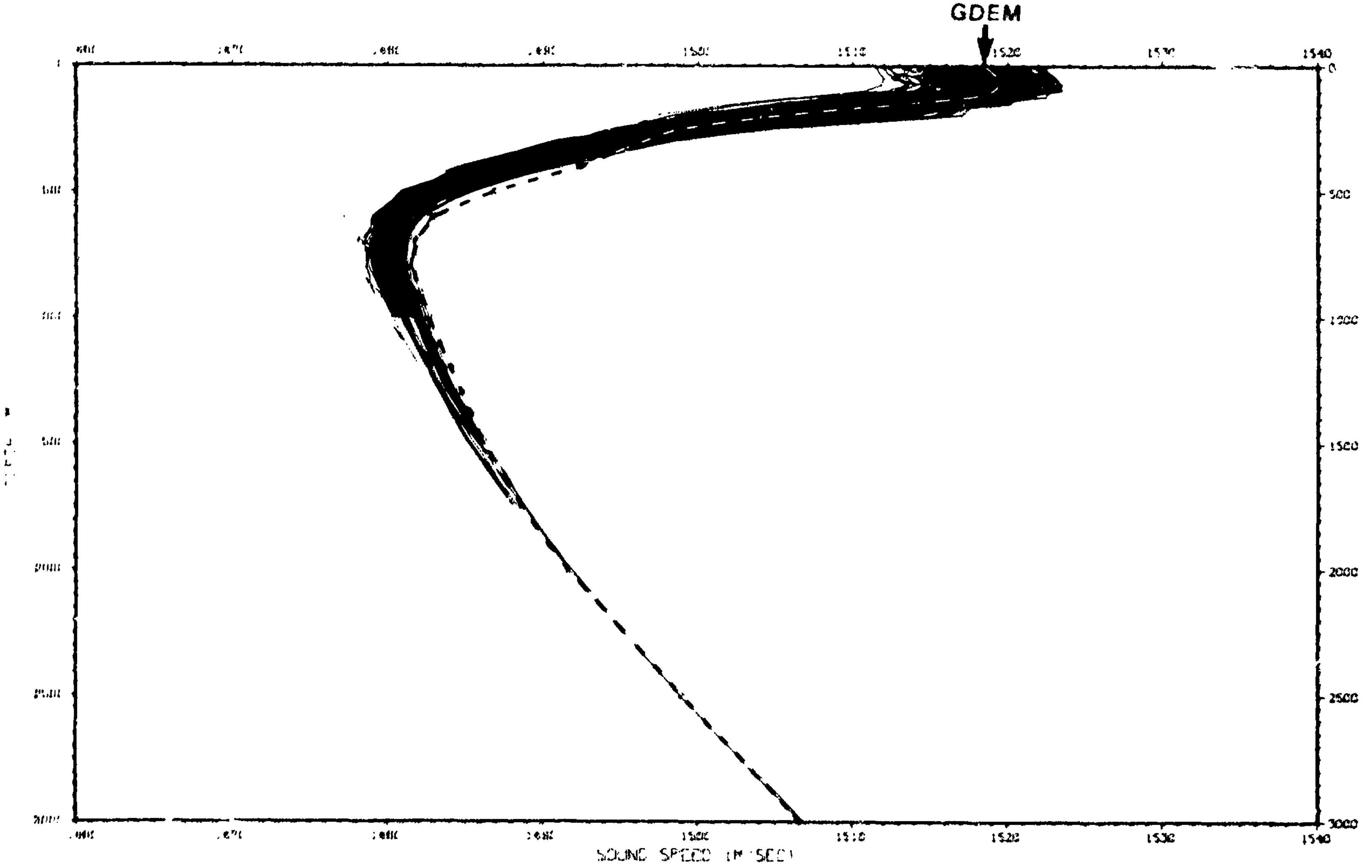


Fig. C.14--GDEM profile overplotted on composite plot of all deep profiles, location 1, winter

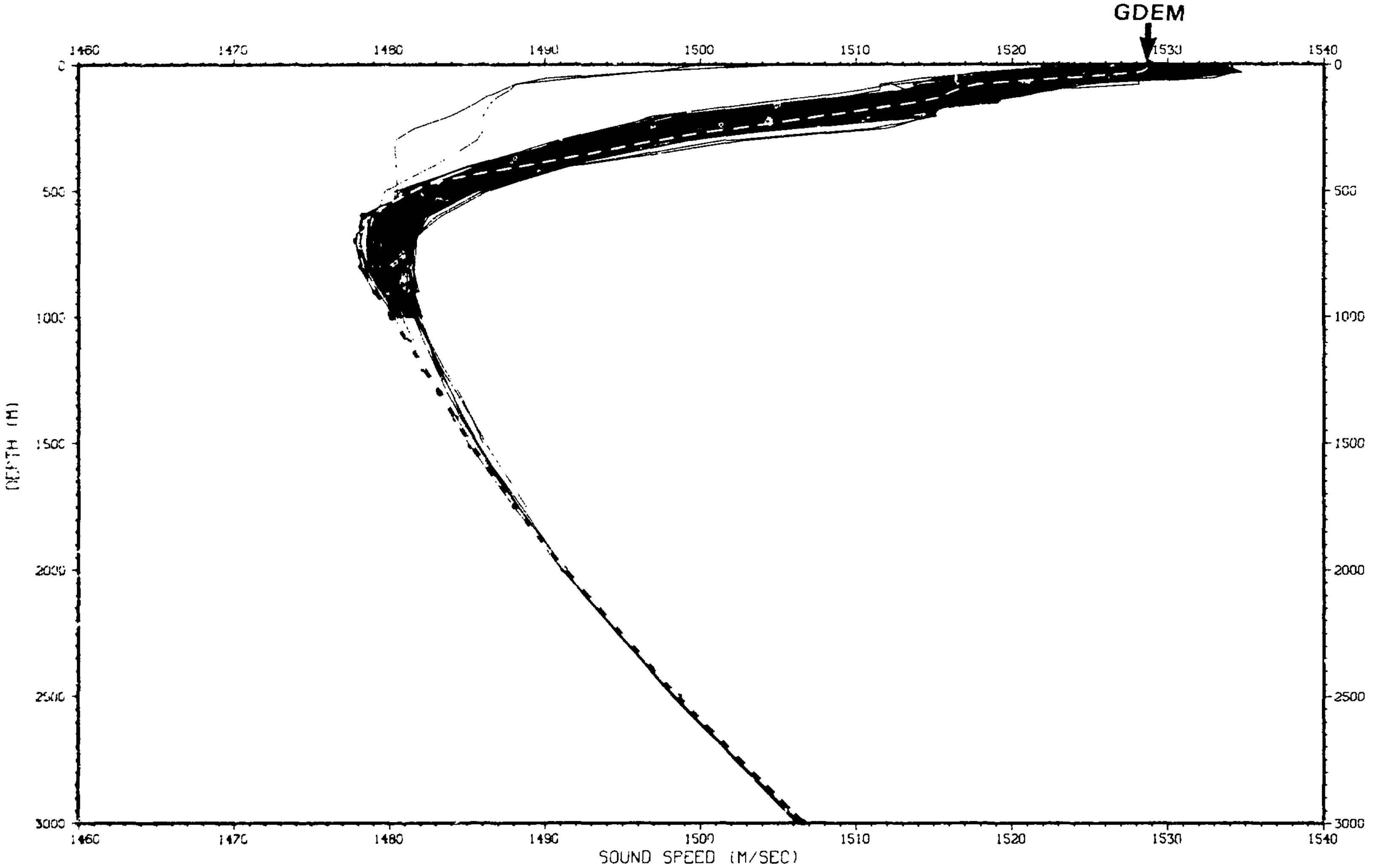


Fig. C.15--GDEM profile overplotted on composite plot of all deep profiles, location 1, summer

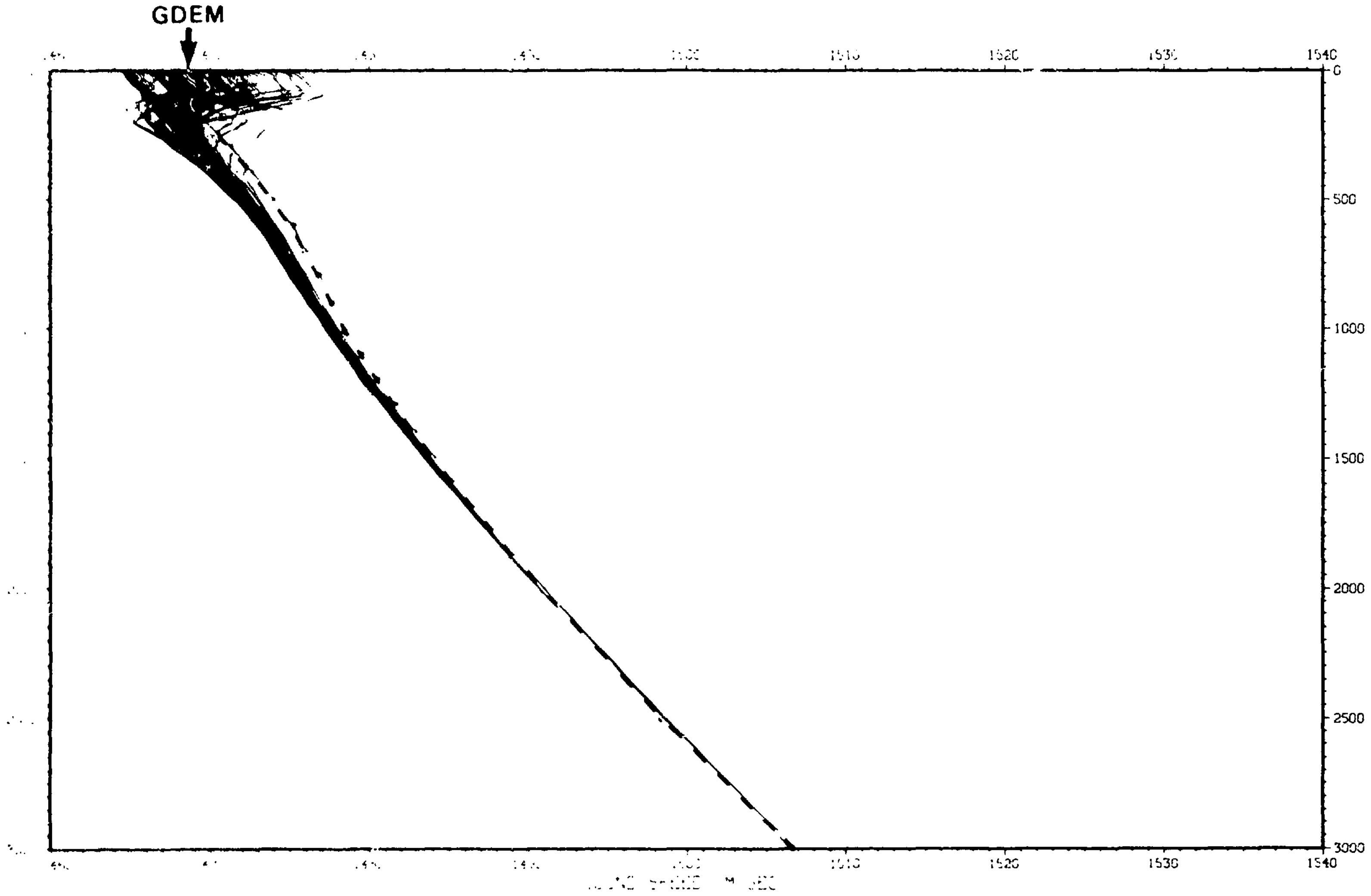


Fig. C.16--GDEM profile overplotted on composite plot of all deep profiles, location 2, winter

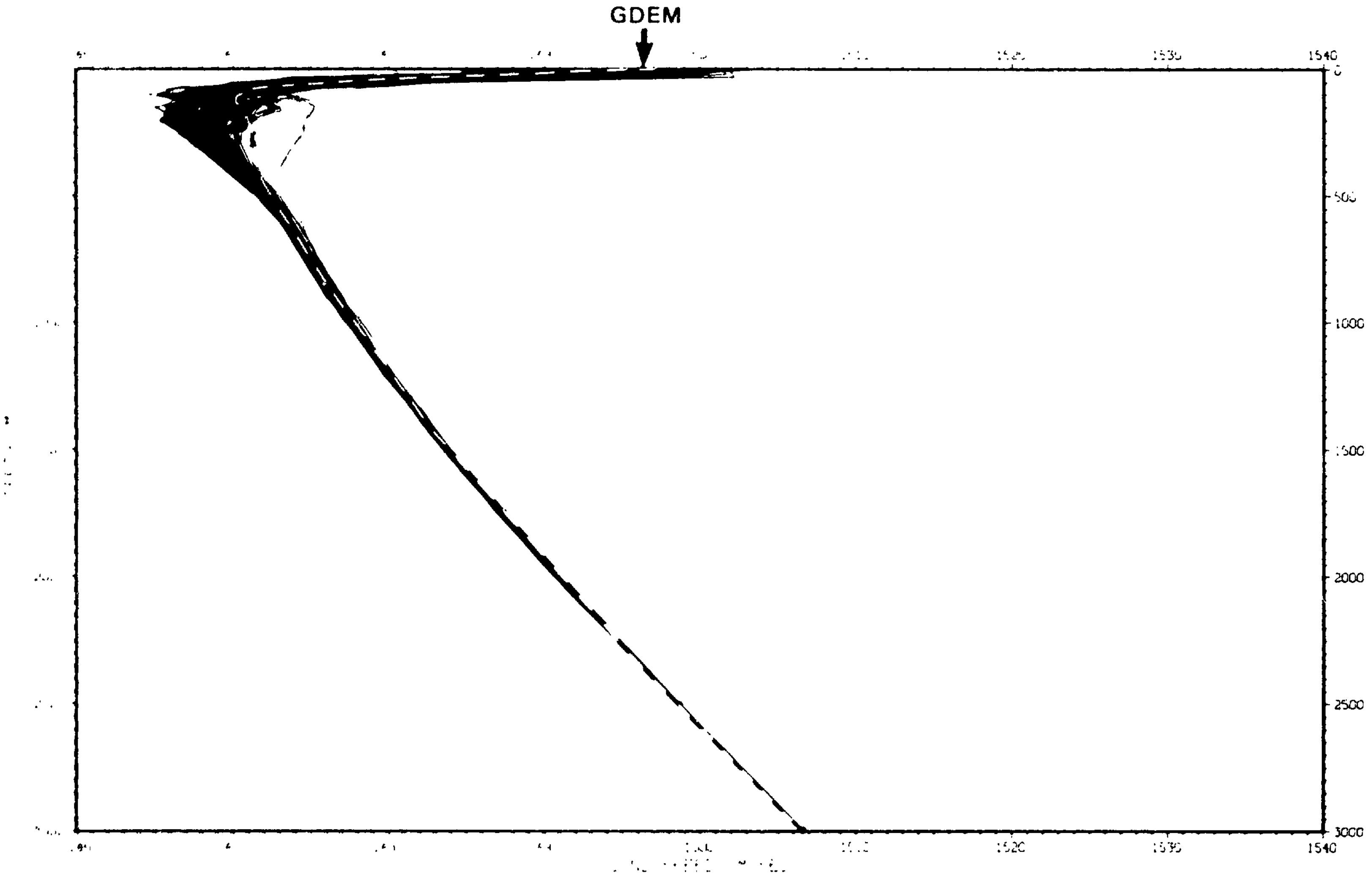


Fig. C.17--GDEM profile overplotted on composite plot of all deep profiles, location 2, summer

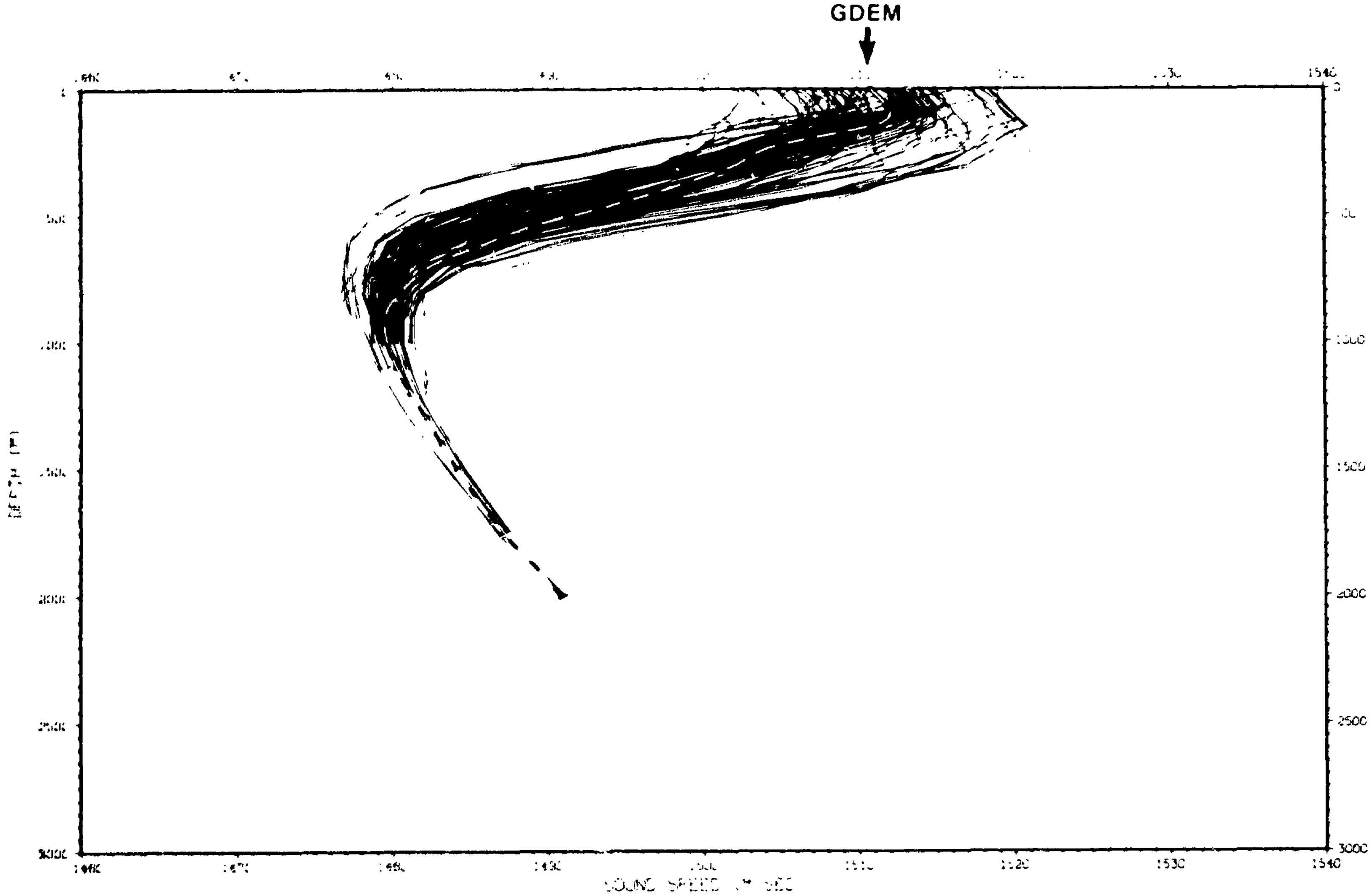


Fig. C.18--GDEM profile overplotted on composite plot of all deep profiles, location 3, winter

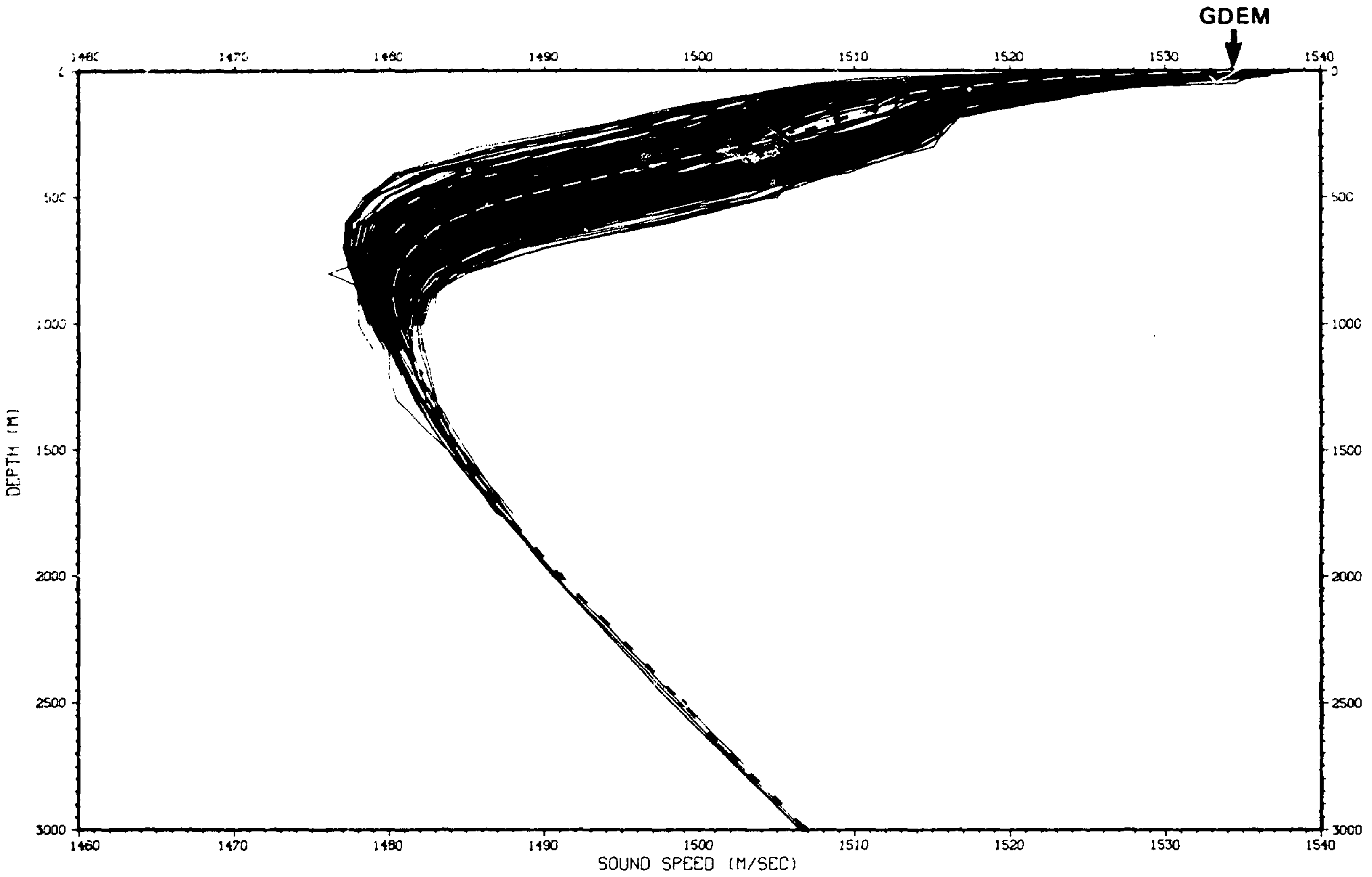


Fig. C.19--GDEM profile overplotted on composite plot of all deep profiles, location 3, summer

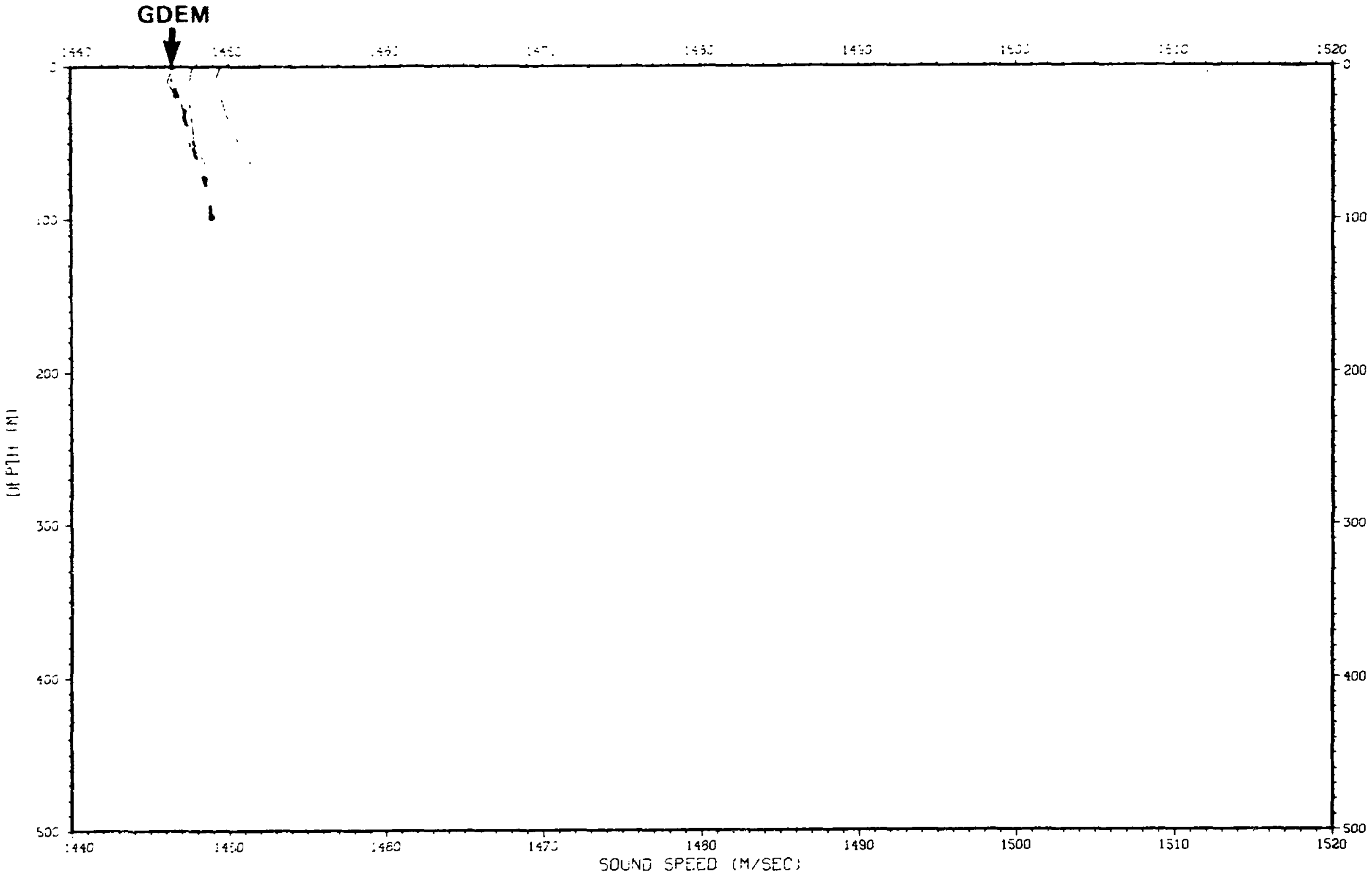


Fig. C.20--GDEM profile overplotted on composite plot of all deep profiles, location 4, winter

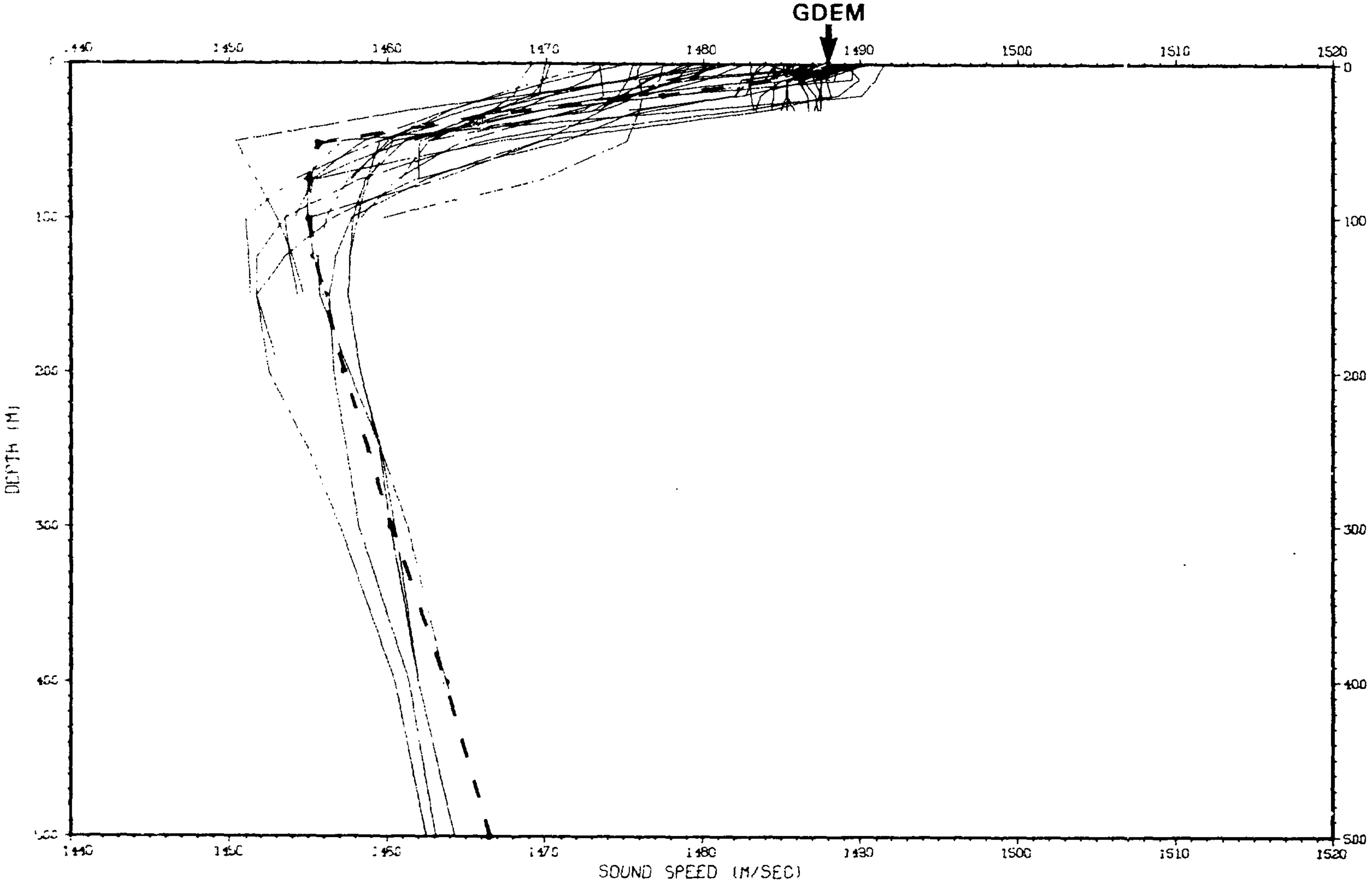


Fig. C.21--GDEM profile overplotted on composite plot of all deep profiles, location 4, summer

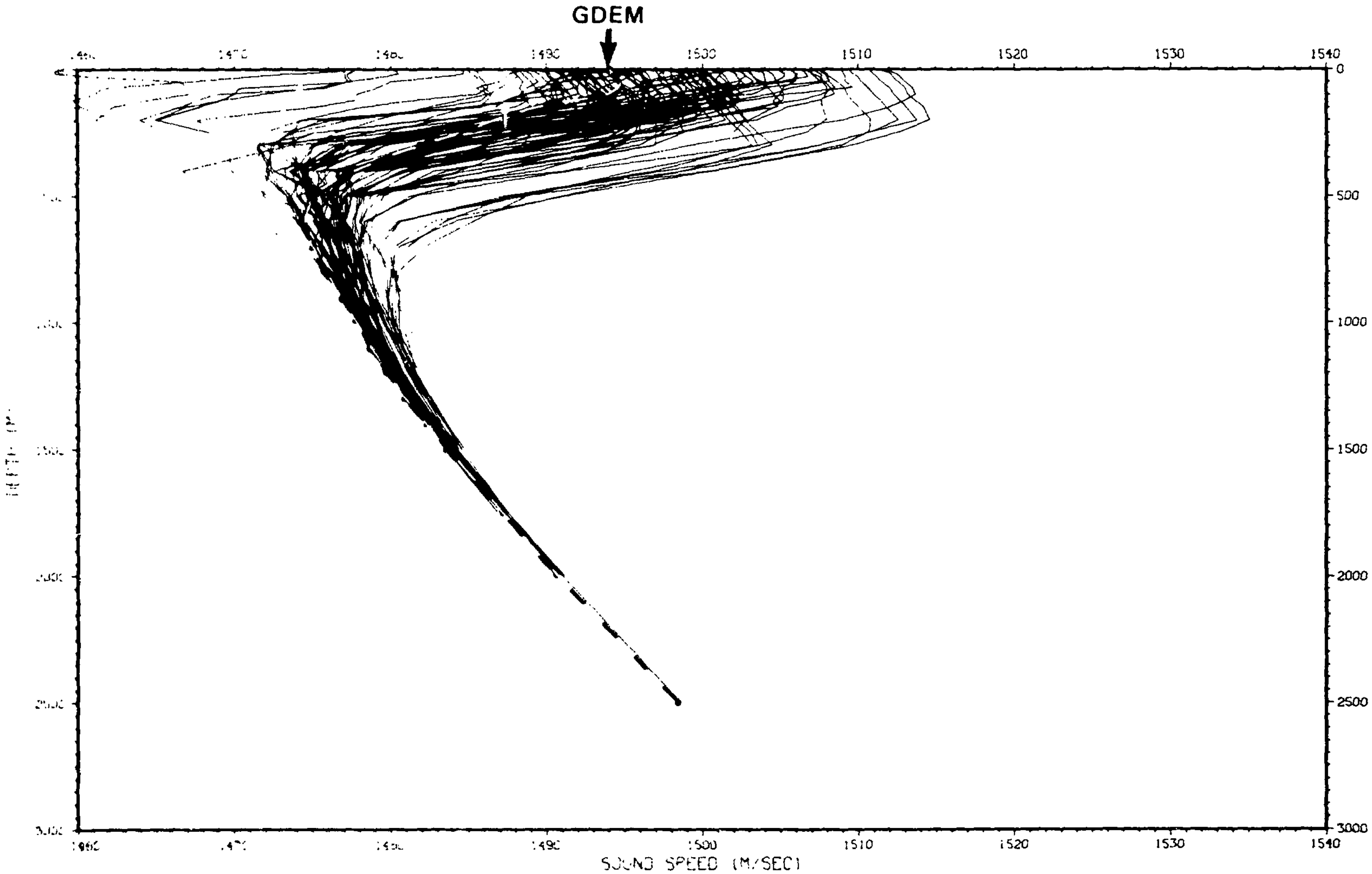


Fig. C.22--GDEM profile overplotted on composite plot of all deep profiles, location 5, winter

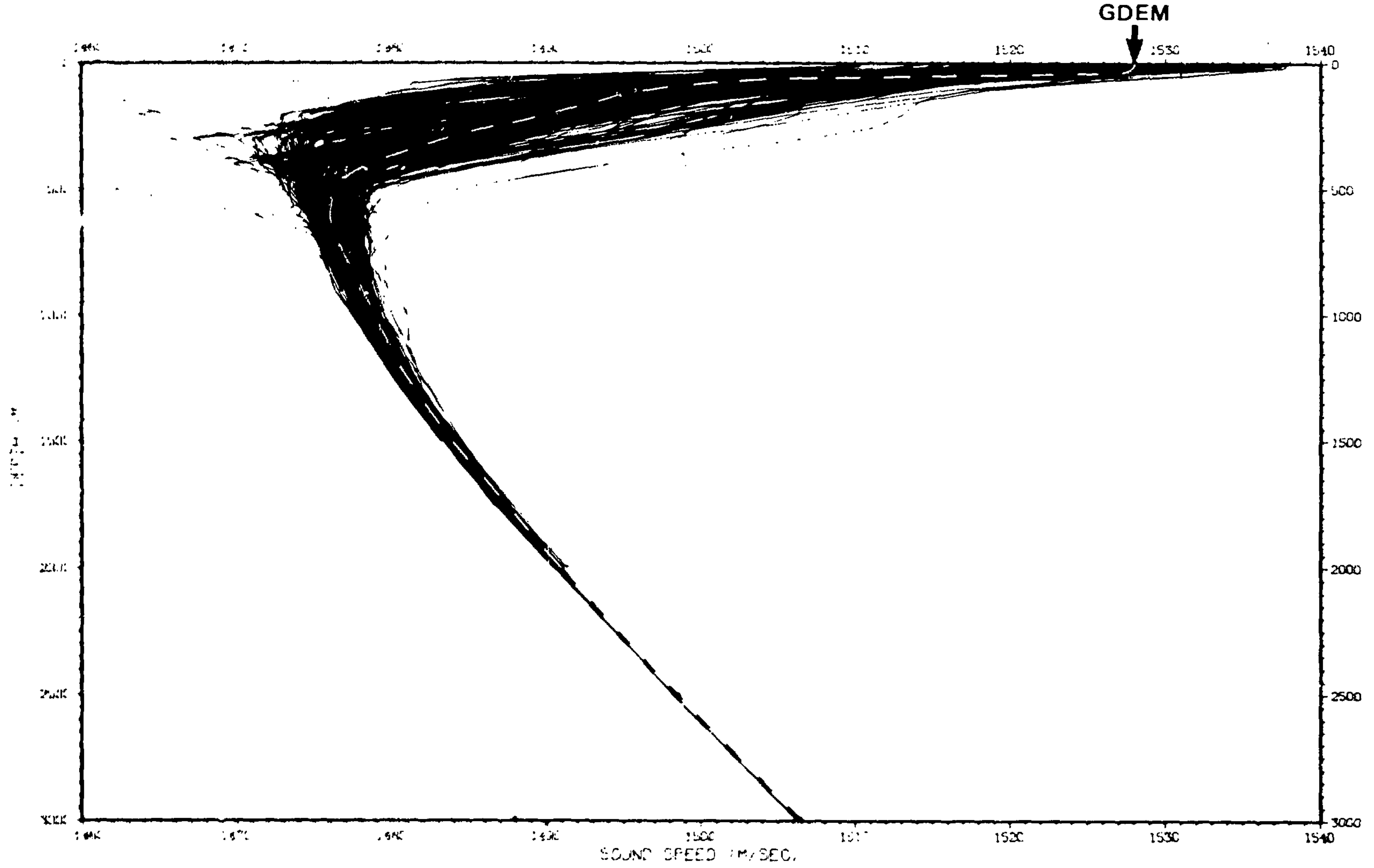


Fig. C.23--GDEM profile overplotted on composite plot of all deep profiles, location 5, summer

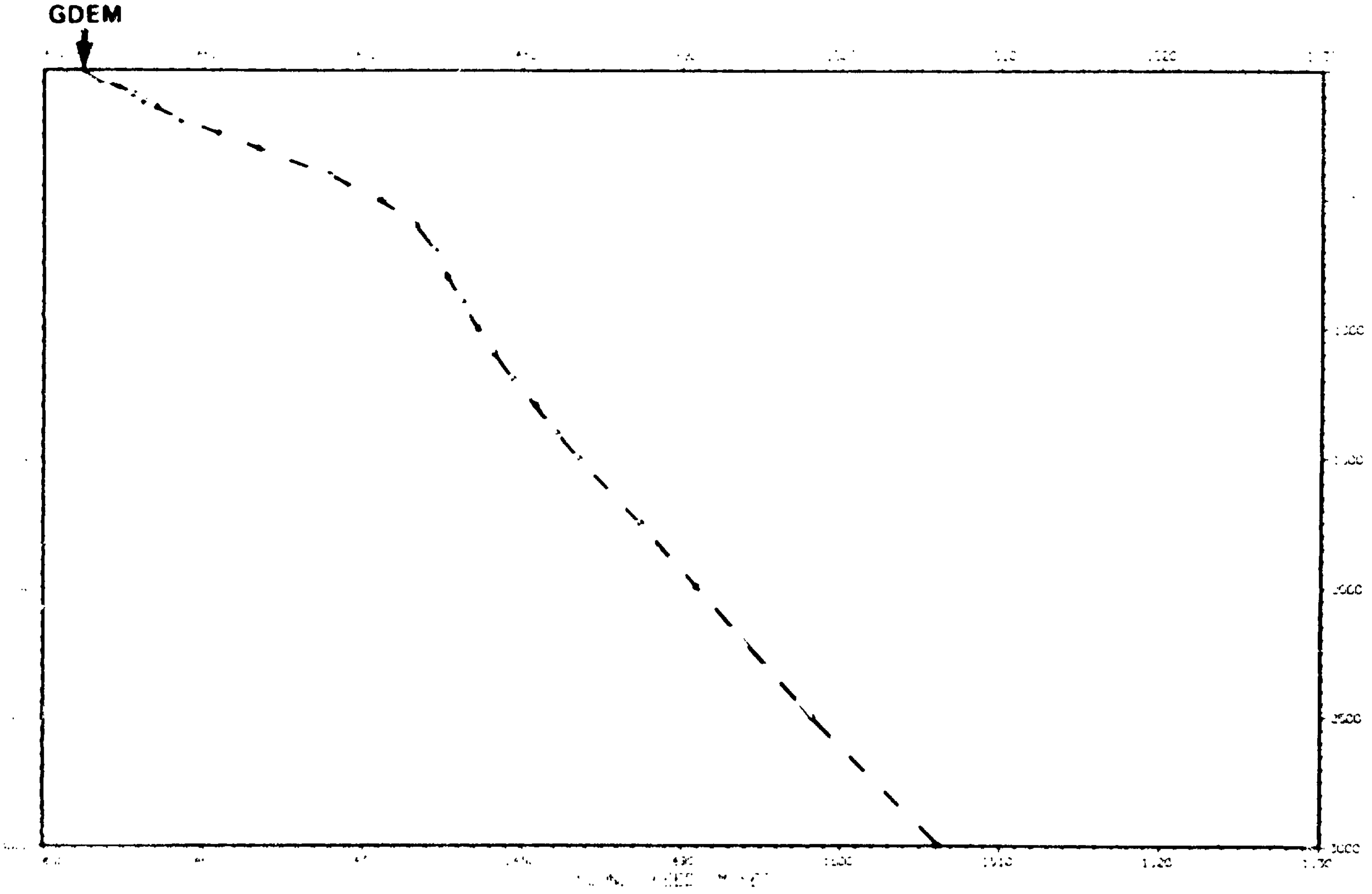


Fig C.24--GDEM profile overplotted on composite plot of all deep profiles, location 6, winter

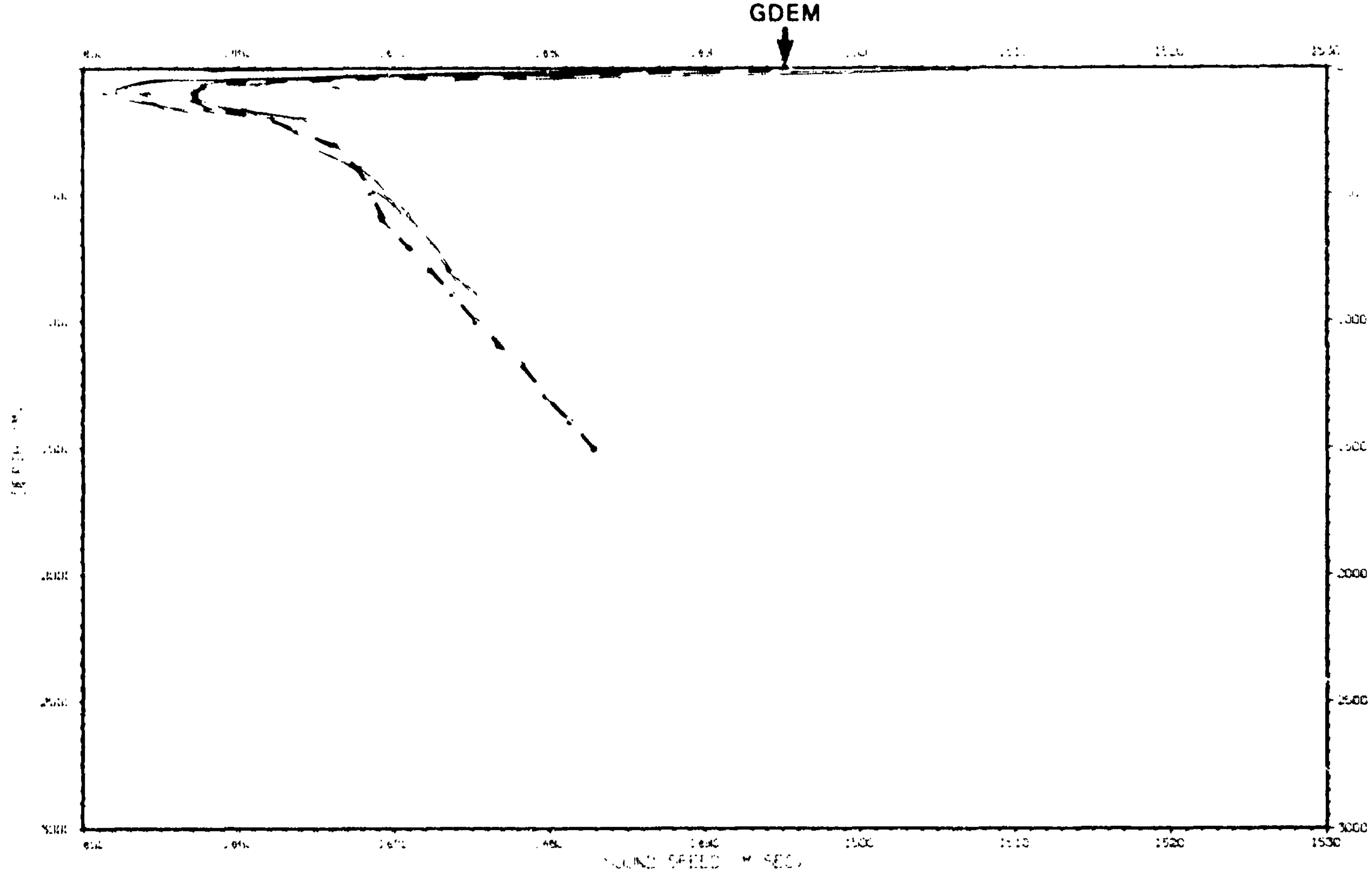


Fig. C.25--GDEM profile overplotted on composite plot of all deep profiles, location 6, summer

Location 1. Figures C.2 and C.3 indicate that the shapes of the typical profile and the GDEM output are similar in winter and summer. However, comparison of just the GDEM profiles for winter and summer indicates a large sound-speed difference extending to a depth of 2000 m. That seasonal difference is not found in the typical profiles or in the observed data sets containing more than 400 observations for each season. Figures C.14 and C.15 also indicate that the GDEM middepth sound speeds fall positively outside the data envelope during the winter and negatively outside during the summer. That variation in the GDEM output cannot be readily explained by known oceanographic seasonal variability for the area. The potential problem appears to lie in the middepth sound-speed portion of the model; further investigation is needed to make certain.

Location 2. The structural comparison for winter (Fig. C.4) looks reasonable, though the GDEM profile falls outside the observed data envelope on the positive side. This is also apparent in the overplot of the GDEM profile on the composite profile (Fig. C.16). The summer profile (Fig. C.5) appears similar to the typical, but a portion deviates positively from the observed data set (also indicated in Fig. C.17). These profile mismatches resemble the mismatches encountered in the earlier comparisons, so the redesigned upper-layer model may correct both. We expect to evaluate the new GDEM when model output is available in FY 1980.

Location 3. Figures C.6 and C.7 indicate a reasonably good match in the comparisons. Both GDEM and typical profiles indicate seasonal deviations at depths below the normal seasonal limit of 100-200 m. An explanation is suggested by the composite plot for the summer (Fig. C.19). The historical transit of the southern part of the subtropical-subarctic transition zone past location 3 is apparent in the bimodal structure of the upper thermocline. The GDEM model produces an intermediate structure while the selection procedure for the typical profile targets the shallow thermocline data subset.

Location 4. The selection of location 4 was an attempt to check the GDEM model in semi-isolated shallow water. However, insufficient data in the winter (see Fig. C.20) and high variability in the summer

(Fig. C.21) precluded a meaningful model comparison. The evidence in Figs. C.8 and C.9 suggests that the model predicted quite well the general sound-speed structure for this location.

Location 5. Location 5 is also in an area of high variability, as the composite plots in Figs. C.22 and C.23 show. The GDEM output profile compares quite favorably with the typical and composite data during the summer. The winter structure is similar, but Figs. C.8 and C.22 show a slight negative shift of the profile. No explanation is apparent.

Location 6. Location 6 comparisons are inconclusive because of the lack of observational data. The winter season contained only one observation, and few data were available for the summer. The GDEM-composite profile overlays in Figs. C.24 and C.25 show generally similar structures. A tendency toward mismatch is seen in the depth zone where the model is being redesigned. The new model will be evaluated for location 6 in FY 1980.

In summary, GDEM exhibits the same potential to reasonably model the oceanic sound-speed structure for acoustic modeling that it did in the earlier comparisons. The problem remaining with upper-structure modeling at higher latitudes may already have been solved by the redesign. We do not know whether the redesign will correct the second problem noted, the apparent seasonal shift observed in the GDEM profiles for location 1. That anomaly does not, however, seriously impair the model's potential for reasonably reproducing vertical structure and acoustic transmission. Further evaluation in FY 1980 will reveal more about the seasonal-shift phenomenon.

Horizontal Integrity

For Standard Ocean application, it is important that GDEM preserve the horizontal integrity of the structure for range-dependent acoustic modeling. Judging by the development procedures used to produce GDEM, preservation of horizontal integrity will be a fundamental asset of the model.

NAVOCEANO gave NOSC a limited opportunity to test this characteristic by providing a single GDEM-produced sound-speed contour for evaluation. The contour pertained to a section of the great-circle track (Fig. C.26) extending from 30° to 45°N through the Kuroshio and Oyashio frontal zones in the Northwest Pacific (Fig. C.27). Archival observed data have not been processed for comparison with the GDEM section, but data in the literature allow indirect evaluation. The key aspects of model output to consider are the frontal zone gradients and the absolute sound-speed values.

We used two synoptic sound-speed sections reported by Roden for comparison.[*] The first is a north-south section at 168°E and at the same latitudes as the GDEM section, for April. Although located considerably east of the GDEM section, the Roden section shows a horizontal gradient of 24 m/s/1° lat at 200 m depth at the subarctic front that compares with the GDEM section at the Oyashio frontal zone. It is difficult to distinguish contours and to compare structure in the upper 200 m on the GDEM plot, and the season it represents is unknown. The second Roden section at 154°E for April provides a very good comparison.[†] The gradient across the Kuroshio front in this Roden section is approximately 28 m/s/1° lat at 200 m depth, while the GDEM gradient is somewhat less at 15-20 m/s/1° lat. Across the Oyashio front the gradients are very similar at approximately 25 m/s/1° lat.

These remarkable results indicate that smoothing and editing techniques used in the preprocessing of data for GDEM do not obliterate significant high-gradient structural features such as large frontal zones. In FY 1980, more comprehensive range-dependent testing of the model should be performed to evaluate the horizontal field output.

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[*] G. I. Roden, "Temperature and Salinity Fronts at the Boundaries of the Subarctic-Subtropical Transition Zone in the Western Pacific," *J. Geophys. Res.*, Vol. 77, No. 36, 1972, pp. 7175-7187.

[†] G. I. Roden, "On North Pacific Temperature, Salinity, Sound Velocity and Density Fronts and Their Relation to the Wind and Energy Flux Fields," *J. Phys. Oceano.*, Vol. 5, No. 4, 1975, pp. 557-571.

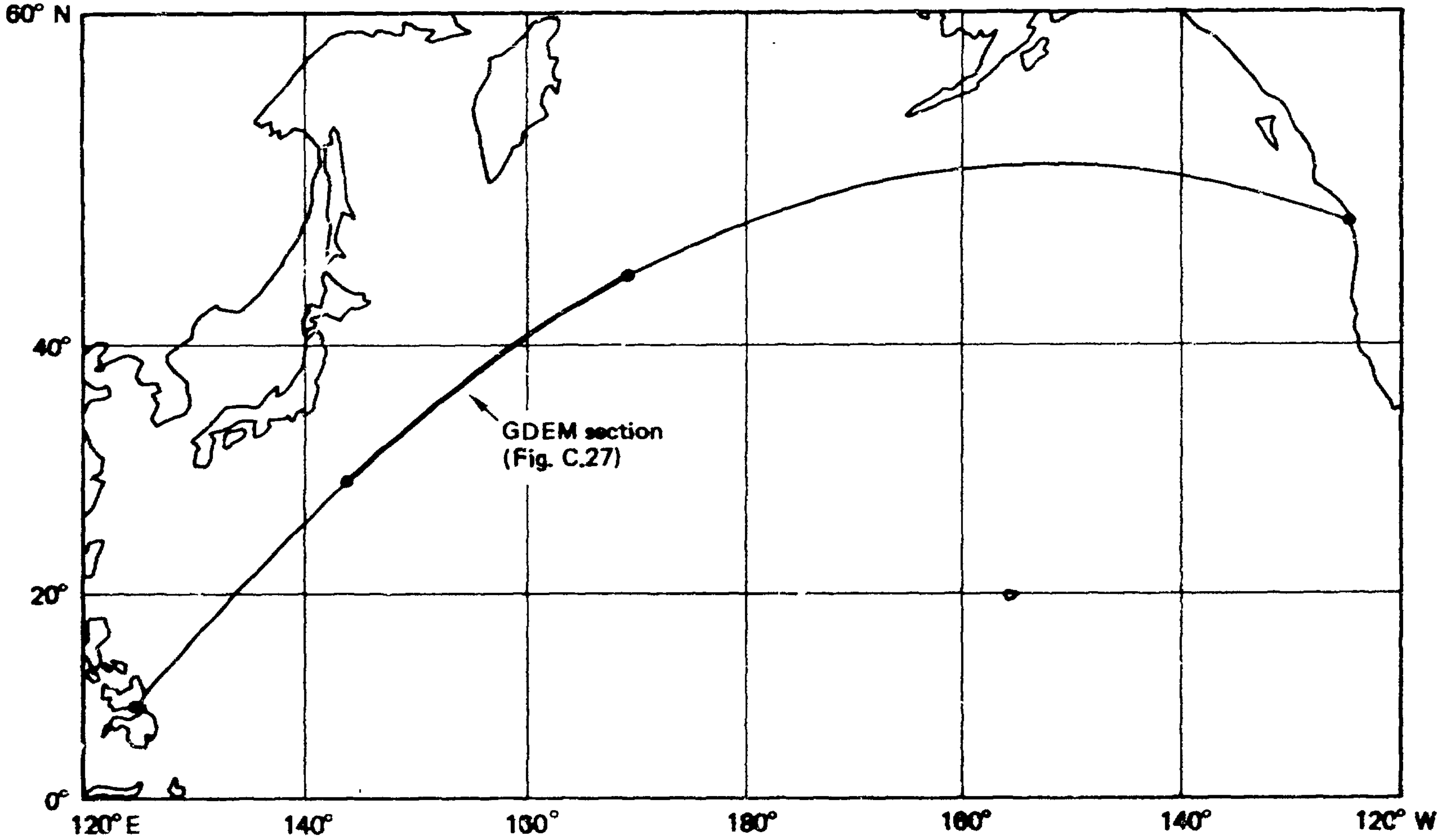

Fig. C.26--Great-circle track, North Pacific Ocean

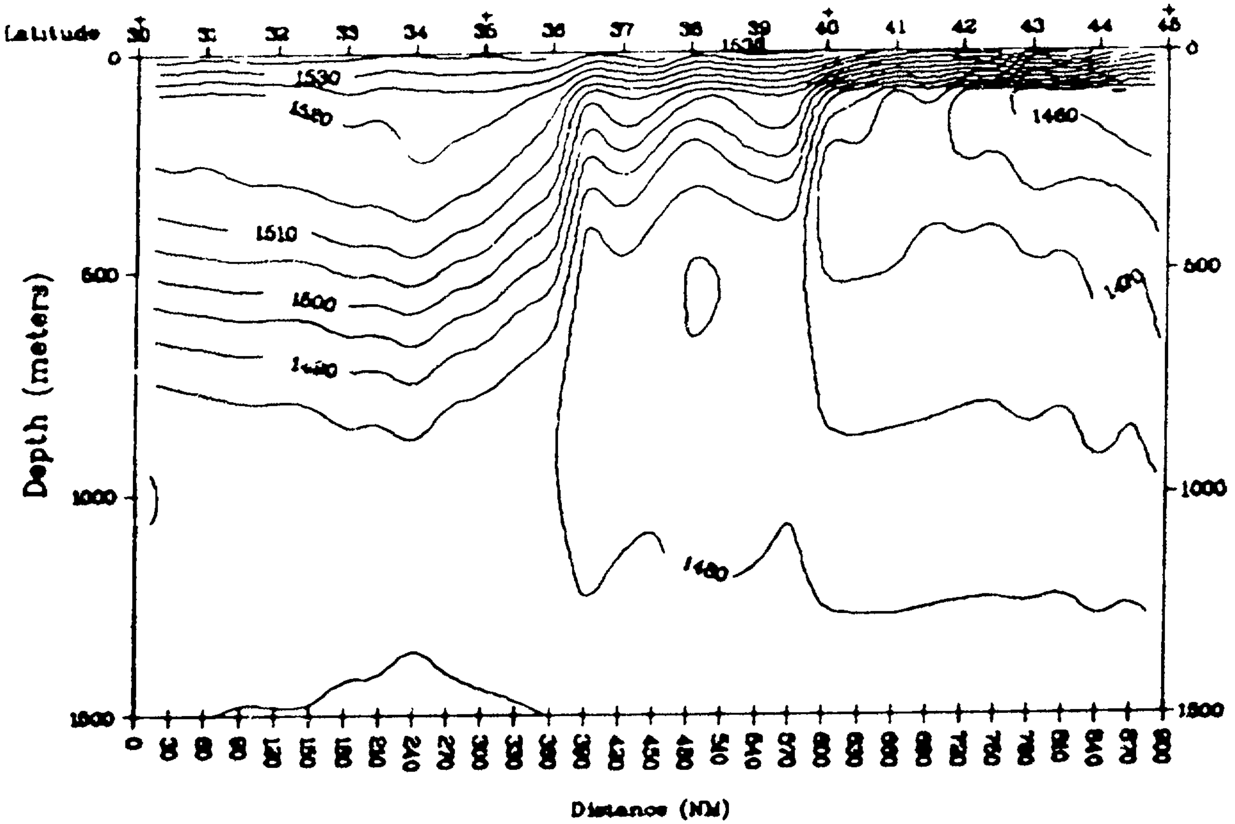

Fig. C.27--GDEM contour of sound-speed field, 30°-45°N, Pacific Ocean (along great circle track shown in Fig. C.26)

Attachment 1

DESCRIPTION OF TECHNIQUES USED FOR DEVELOPMENT OF SOUND SPEED PROVINCES FROM THE NAVOCEANO 3D MODEL*

INTRODUCTION

The data set used in deriving the Province Chart is actually a three-dimensional seasonal model of sound speed. The model consists of three parts: a surface model of the upper 400 meters consisting of annual salinity and seasonal temperature (3 months); a two season sound speed model from 200m to 2450m; and a one season deep sound speed model from 2000m to the bottom. A bathymetry file is also included.

DATA BASE

The basic data base is our Ocean Station File (OSTA) which contains all available Nansen cast data. This file was used for all parameters. To better define the near surface model seasonally, a XBT file supplemented the temperature portion of the model.

DATA EDITING

There are two phases to the data editing--automatic and manual.

The automatic method consists of a computer routine which does the following:

1. Breaks the region into small squares.
2. Computes mean and standard deviation of data within each square.
3. Eliminates all data outside ± one standard deviation from mean.

In practice, a double pass is made shifting the squares to better evaluate stations which may have been on the border. For deep sound speed data a 5 degree square is used and each level is evaluated separately.

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*Unpublished technical description by NAVOCEANO, Code 3300, spring 1979.

For data which consists of a set of coefficients for each station, a different approach is used. The profile is derived from the coefficients and a mean profile for the entire data set is computed. All stations are compared with this mean profile deriving an unnormalized coherency coefficient for each station. These coherency coefficients are then used as the values in editing. A two-degree square is used. At this point season becomes important and it is at this stage that the seasons are separated. A separate run is therefore required for each season.

The manual procedure consists of contouring the data, locating questionable areas, listing the stations within and near these areas, manually selecting the bad stations and running a cleanup routine to create a new data tape without the bad stations.

CURVE FITTING METHODS

The heart of the basic model is the orthogonal polynomial least squares fit to each input profile of sound speed. One of the problems with the orthogonal polynomial is that very large changes, as occur near the sea surface, are not only poorly fit, but also cause a rippling effect down the profile. For this reason the upper 200m were not originally used. This curve fitting technique is used on the sound speed profiles between 200m and 2450m. The routine requires evenly spaced data and an even number of input points. The data are therefore interpolated using a cubic spline every 50m creating 46 data points.

Representative profiles were fit using the polynomial and the RMS was computed for each degree of fit. The objective was to have the mean RMS no larger than 1 m/sec. The minimum degree of fit meeting that requirement is seven producing eight coefficients.

The same technique is used for salinity from 0-380m with a three degree fit.

The deep portion of the sound speed profile, 2500m to the bottom, is very smooth and a non-orthogonal least squares parabolic fit with three coefficients suffices. This fit is actually made starting at 2000m to provide overlapping.

The near surface (0-400m) temperature is the most complicated with typical profiles simulating a step function. For this fit an analytical expression for the squared amplitude response of a Butterworth filter was developed. This technique works quite well with most profiles being fit with an RMS of less than 0.3°C and no rippling below the mixed layer.

SPATIAL INTERPOLATOR

A three-stage interpolator is used to produce matrices of the coefficients. The first stage assigns each value to a grid point weighted as a function of the inverse square of the distance from the grid point. If any data fall within 0.1 grid interval of the grid point those data are arithmetically averaged and others excluded.

The second stage builds a coarse smooth grid at 3 times the requested grid spacing. This uses a minimum curvature cubic spline technique which fits a surface to the data. The technique was developed by I. C. Briggs (1974) and programmed by C. J. Swain (1976). The coarse grid is filled in using a cubic spline to produce a smooth surface at the final grid spacing of 30 minutes in latitude and longitude.

The third stage merges this smooth grid with the input data. The resultant matrix shows detail where there are data and is smooth where data are sparse with continuity of the first and second partial derivatives maintained throughout.

COMPRESSION AND RETRIEVAL

After the grids have been evaluated for bad points, they are run through a series of compression, sorting, and indexing routines. In preparation for this, the grids are organized so that each season of the near surface includes the bathymetry grid, the salinity coefficient grids, and the temperature coefficient grids for that season. Thus each season consists of a complete set for retrieval. The deeper sound speed coefficient grids are also combined with bathymetry. This results in six compressed and sorted files: four seasonal near-surface files and two seasonal deep files.

Retrieval routines simply require a position and season and the appropriate profile is returned. To get a surface to bottom profile requires accessing both a near-surface file and a deep file.

Therefore, to simplify usage, a user file is built for each season which consists of reconstructed sound speed profiles from surface to bottom and salinity and temperature profiles to 400m at 30' positions. These exist in the user file similar to an oceanographic station with values at standard depths.

The creation of a complete sound speed profile from surface to bottom requires two merges--one at 400m and the other at 2500m, connecting the three parts of the model. The sound speed from the surface to 400m is derived from the temperature and salinity models and is merged using a modified version of the ICAPS merge. This merge consists of accenting the upper profile and shifting the deep to fit, applying a correction which decreases with depth. In order to account for the different time steps between the surface model and the deep model, this merge has been modified to apply the same corrections in reverse to the upper profile when the difference between the two at 400m is large.

The deep merge is accomplished with a 10 point overlap and differential weighting. This takes place between 2000 and 2450m with a point every 50m. At 2000m the upper profile is weighted 10 and the deep profile 1 while at 2450m the upper profile is weighted 1 and the deep profile 10.

REFERENCES

Briggs, I. C., "Machine Contouring using Minimum Curvature" Geophysics, Vol. 39:1, pp. 39-48, 1974.

Swain, C. J., "A Fortran IV Program for Interpolating Irregularly Spaced Data using the Difference Equations for Minimum Curvature" Computers and Geosciences, Vol. I, pp. 231-240, 1976.

Attachment 2

INITIAL COMPARISONS BETWEEN GDEM AND TYPICAL OBSERVED PROFILES*

This attachment presents the preliminary results of qualitative tests to examine how well the Generalized Digital Environmental Model (GDEM) reproduces accurate historical sound-speed profiles for numerical acoustic modeling.† For expediency, preselected "typical" sound-speed profiles from the Northeast Pacific region were compared with the GDEM output. The typical profiles were obtained by a NOSC statistical procedure (described by Colborn and Pugh, NUC TN 1006, May 1973) that selects an observed profile to represent all data for a particular sound-speed province over a particular season. Figure 1 shows the six Northeast Pacific provinces (delineated by dotted lines) and the locations of the actual profiles chosen to represent them (black dots indicated by arrows) over the summer months of July through September.

Each typical profile location was given to NAVOCEANO as input to GDEM. Figures 2 through 7 plot the model's output of summer profiles for the six locations with the real typical profiles from the same locations. Quantitative sound-speed differences at standard depths are tabulated on each figure. We gauged acceptable variability by comparing the tabulated differences with the standard deviation for the province data set at each standard depth (standard deviation values are not shown here). The comparison indicated good fittings for provinces 2 and 2T. In the other provinces, the typical-GDEM difference exceeds the standard deviation for all province data over the entire season at a number of depths.

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*This attachment is extracted from "Preliminary Evaluation of Candidates for the Standard Ocean Retrieval System and Next Steps Toward Implementation," memorandum from the present authors to Lcdr. Kirk Evans and John H. Locklin, 30 April 1979.

†These tests are limited to qualitative evaluations because the real data for sound-speed variability at each location are unavailable. This problem is being addressed in additional testing now under way.

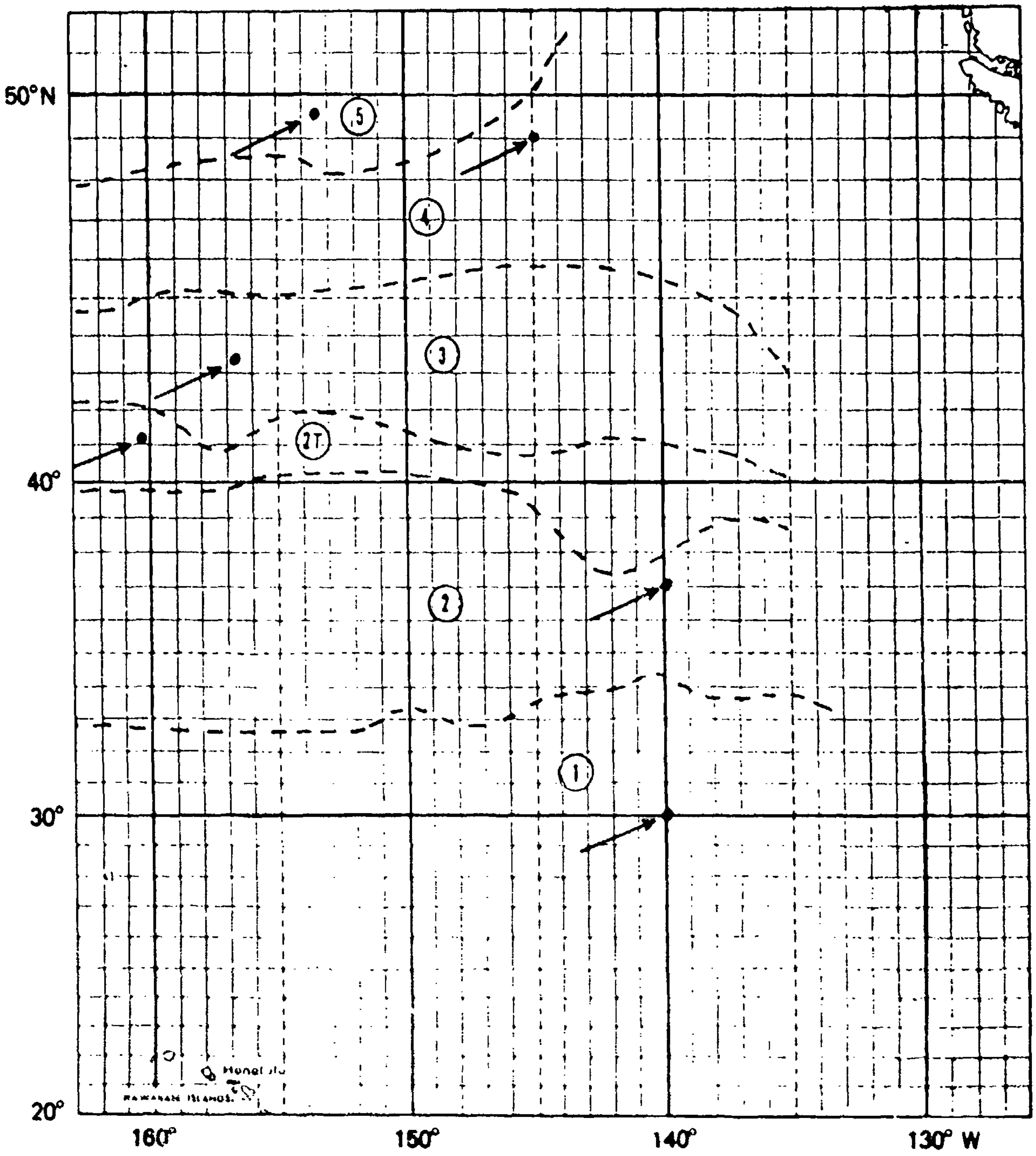
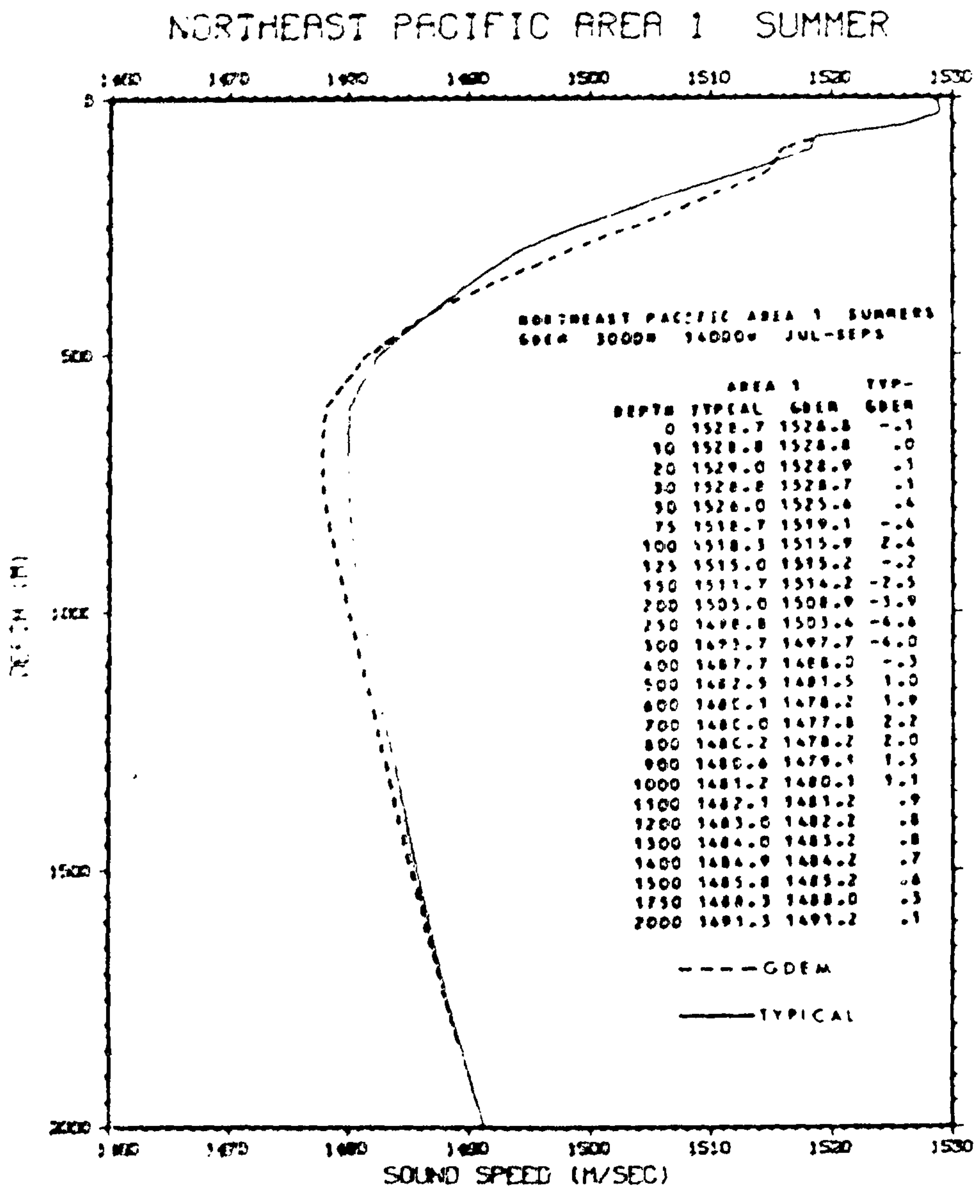


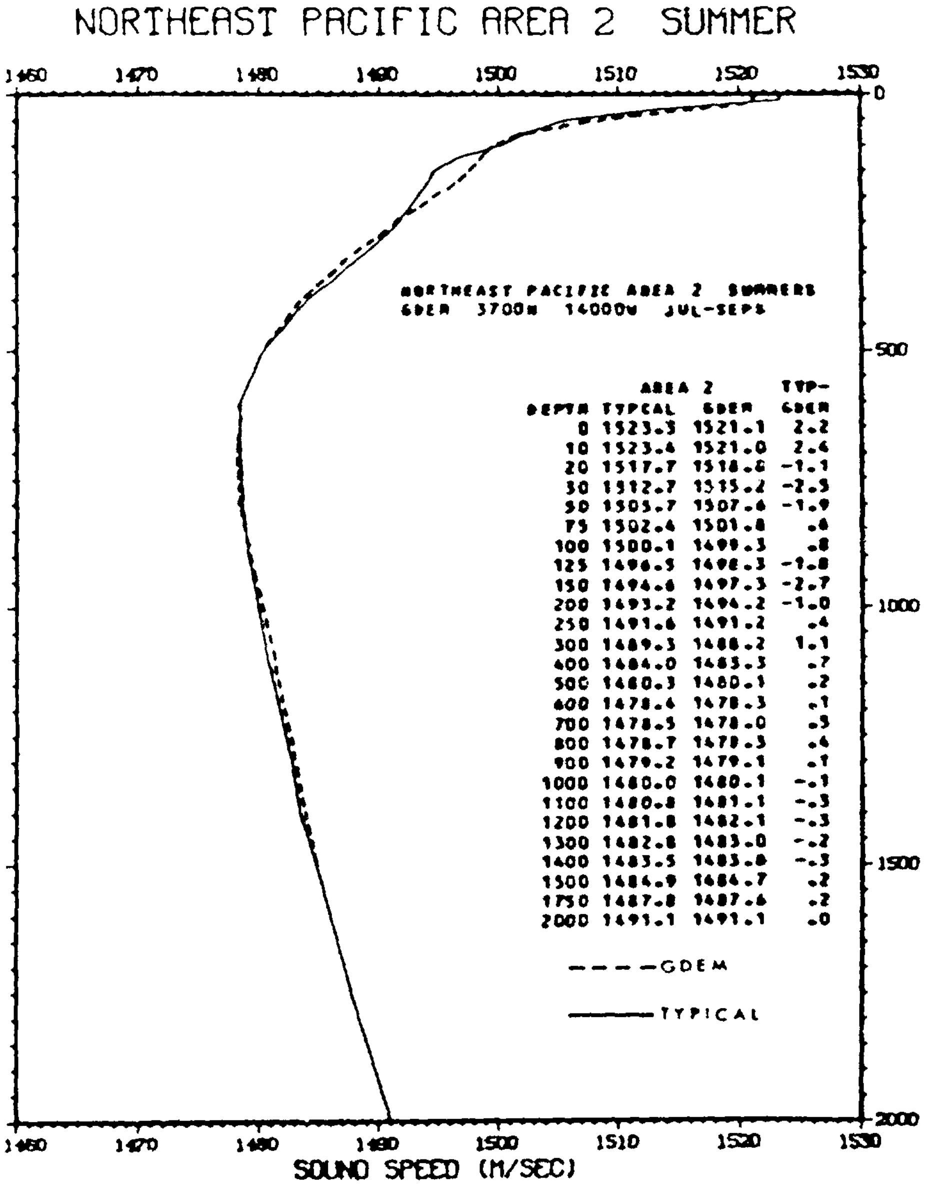
Fig. 1--Location of six selected sound-speed profiles for comparison with GDEM model



NORTHEAST PACIFIC AREA 1 SUMMERS
GDEM 3000N 14000W JUL-SEPS

	AREA 1		TYP-
DEPTH	TYPICAL	GDEM	GDEM
0	1528.7	1528.8	-.1
10	1528.8	1528.8	.0
20	1529.0	1528.9	.1
30	1528.8	1528.7	.1
50	1526.0	1525.6	.4
75	1518.7	1519.1	-.4
100	1518.3	1515.9	2.4
125	1515.0	1515.2	-.2
150	1511.7	1514.2	-2.5
200	1505.0	1508.9	-3.9
250	1496.8	1503.4	-6.6
300	1491.7	1497.7	-6.0
400	1487.7	1488.0	-.3
500	1482.5	1481.5	1.0
600	1480.1	1478.2	1.9
700	1480.0	1477.8	2.2
800	1480.2	1478.2	2.0
900	1480.6	1479.1	1.5
1000	1481.2	1480.1	1.1
1100	1482.1	1481.2	.9
1200	1483.0	1482.2	.8
1300	1484.0	1483.2	.8
1400	1484.9	1484.2	.7
1500	1485.8	1485.2	.6
1750	1488.3	1488.0	.3
2000	1491.3	1491.2	.1

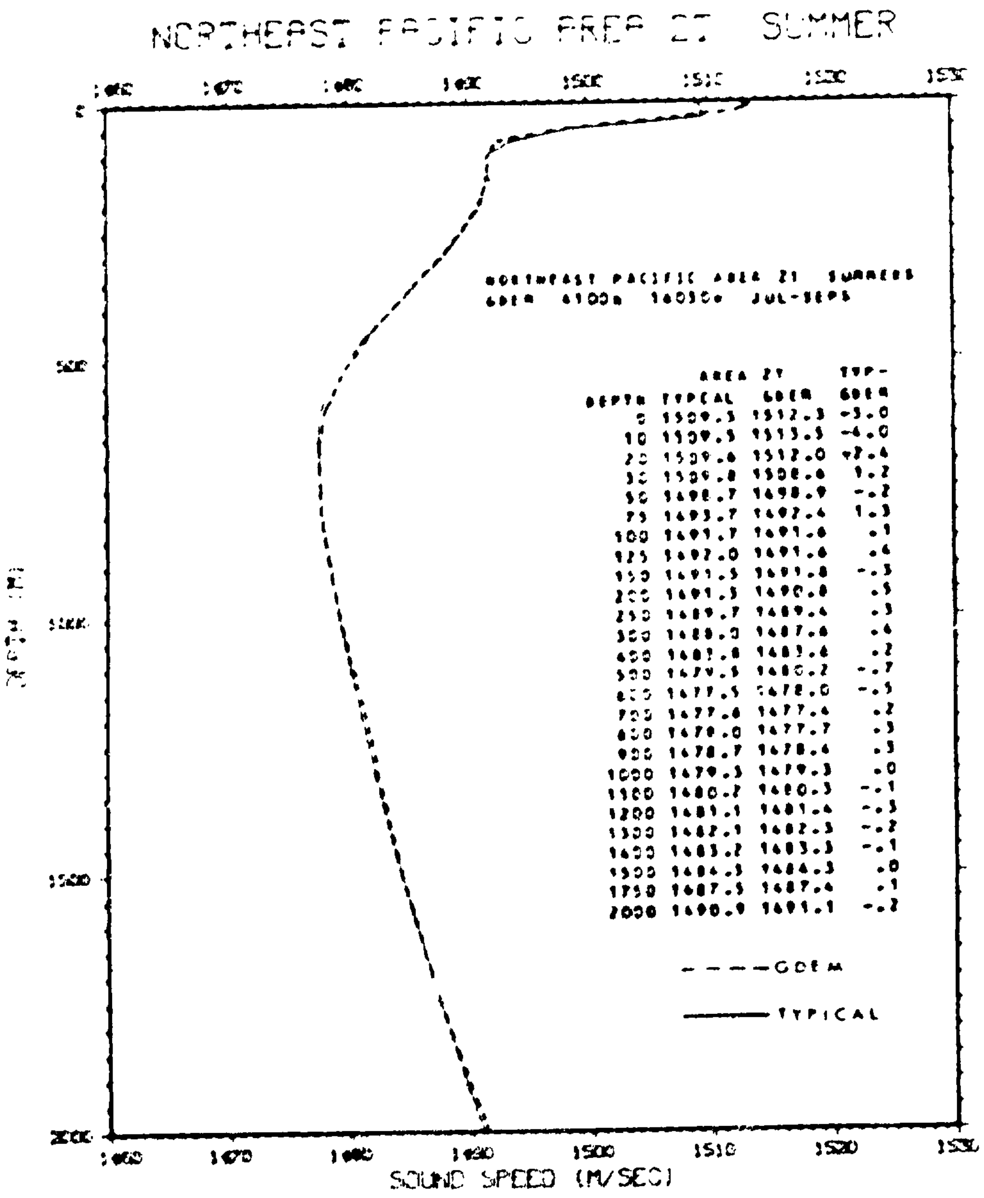
Figure 2



NORTHEAST PACIFIC AREA 2 SUMMERS
GDEM 3700N 14000W JUL-SEPS

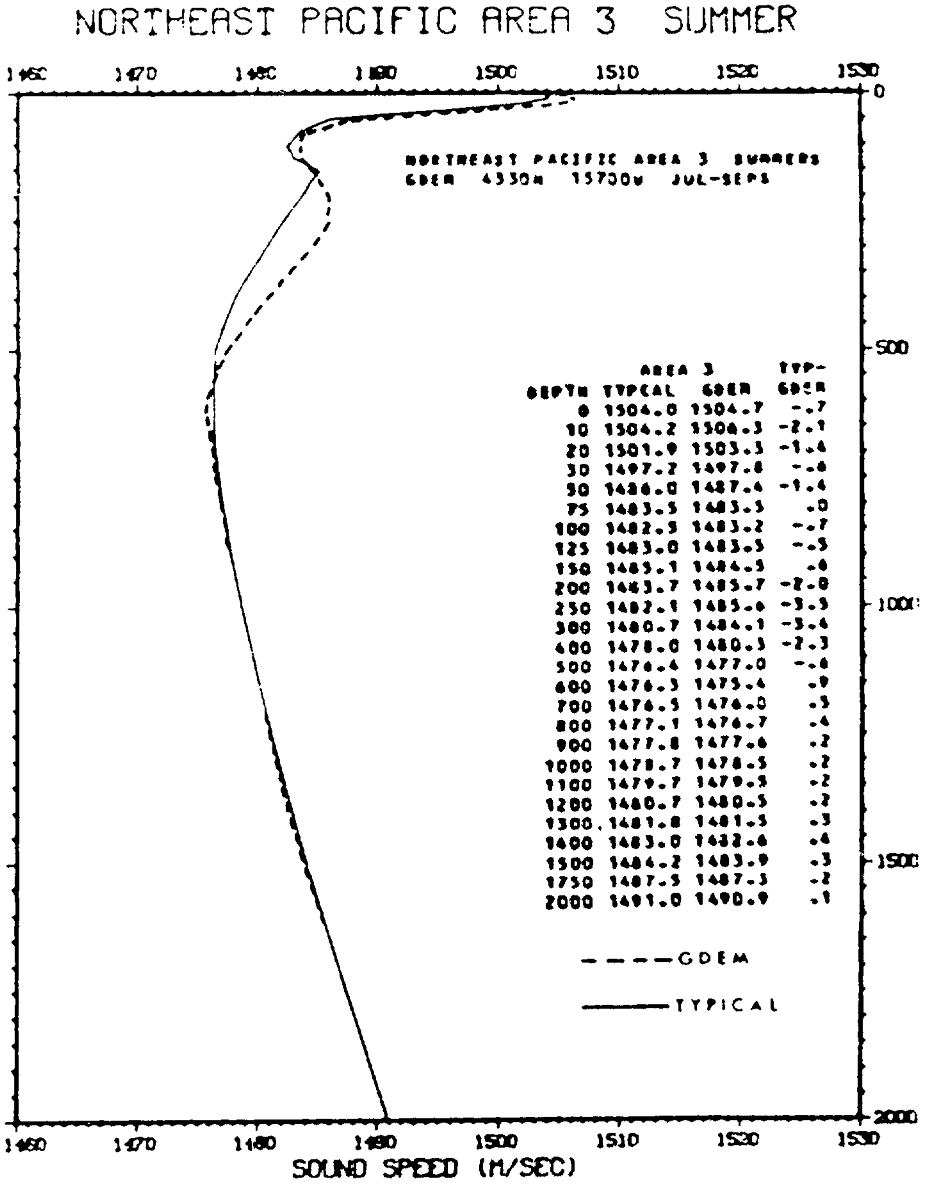
	AREA 2		TYP-
DEPTH	TYPICAL	GDEM	GDEM
0	1523.3	1521.1	2.2
10	1523.4	1521.0	2.4
20	1517.7	1518.8	-1.1
30	1512.7	1515.2	-2.5
50	1505.7	1507.6	-1.9
75	1502.4	1501.8	.6
100	1500.1	1499.3	.8
125	1496.5	1498.3	-1.8
150	1494.6	1497.3	-2.7
200	1493.2	1494.2	-1.0
250	1491.6	1491.2	.4
300	1489.3	1488.2	1.1
400	1484.0	1483.3	.7
500	1480.3	1480.1	.2
600	1478.4	1478.3	.1
700	1478.5	1478.0	.5
800	1478.7	1478.3	.4
900	1479.2	1479.1	.1
1000	1480.0	1480.1	-.1
1100	1480.8	1481.1	-.3
1200	1481.8	1482.1	-.3
1300	1482.8	1483.0	-.2
1400	1483.5	1483.8	-.3
1500	1484.9	1484.7	.2
1750	1487.8	1487.6	.2
2000	1491.1	1491.1	.0

Figure 3



	AREA 21		TYP-
DEPTH	TYPICAL	GDEM	GDEM
0	1509.3	1512.3	-3.0
10	1509.5	1513.5	-4.0
20	1509.6	1512.0	-2.4
30	1509.8	1508.6	1.2
50	1498.7	1498.9	-.2
75	1493.7	1492.4	1.3
100	1491.7	1491.6	.1
125	1492.0	1491.6	.4
150	1491.5	1491.8	-.3
200	1491.3	1490.8	.5
250	1489.7	1489.4	.3
300	1488.0	1487.4	.6
400	1483.8	1483.6	.2
500	1479.5	1480.2	-.7
600	1477.5	1478.0	-.5
700	1477.6	1477.4	.2
800	1478.0	1477.7	.3
900	1478.7	1478.4	.3
1000	1479.3	1479.3	.0
1100	1480.2	1480.3	-.1
1200	1481.1	1481.4	-.3
1300	1482.1	1482.3	-.2
1400	1483.2	1483.3	-.1
1500	1484.3	1484.3	.0
1750	1487.5	1487.4	.1
2000	1490.9	1491.1	-.2

Figure 4



	AREA 3		TYP-
DEPTH	TYPCAL	GDEM	GDEM
0	1504.0	1504.7	-.7
10	1504.2	1506.3	-2.1
20	1501.9	1503.3	-1.4
30	1497.2	1497.8	-.6
50	1486.0	1487.4	-1.4
75	1483.5	1483.5	.0
100	1482.5	1483.2	-.7
125	1483.0	1483.5	-.5
150	1485.1	1484.5	.6
200	1483.7	1485.7	-2.0
250	1482.1	1485.6	-3.5
300	1480.7	1484.1	-3.4
400	1478.0	1480.3	-2.3
500	1476.4	1477.0	-.6
600	1476.3	1475.4	.9
700	1476.5	1476.0	.5
800	1477.1	1476.7	.4
900	1477.8	1477.6	.2
1000	1478.7	1478.5	.2
1100	1479.7	1479.5	.2
1200	1480.7	1480.5	.2
1300	1481.8	1481.5	.3
1400	1483.0	1482.6	.4
1500	1484.2	1483.9	.3
1750	1487.5	1487.3	.2
2000	1491.0	1490.9	.1

Figure 5

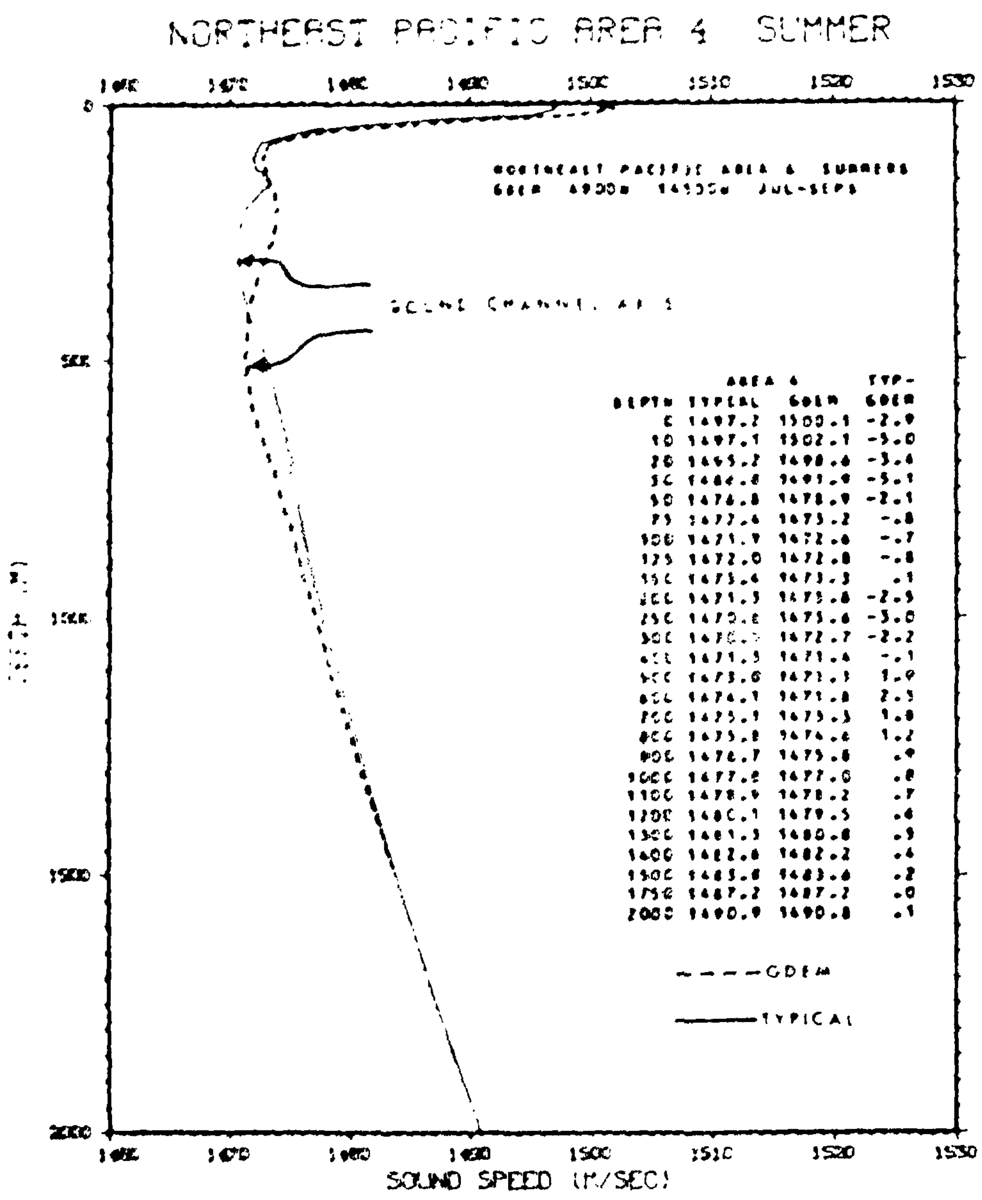


Figure 6

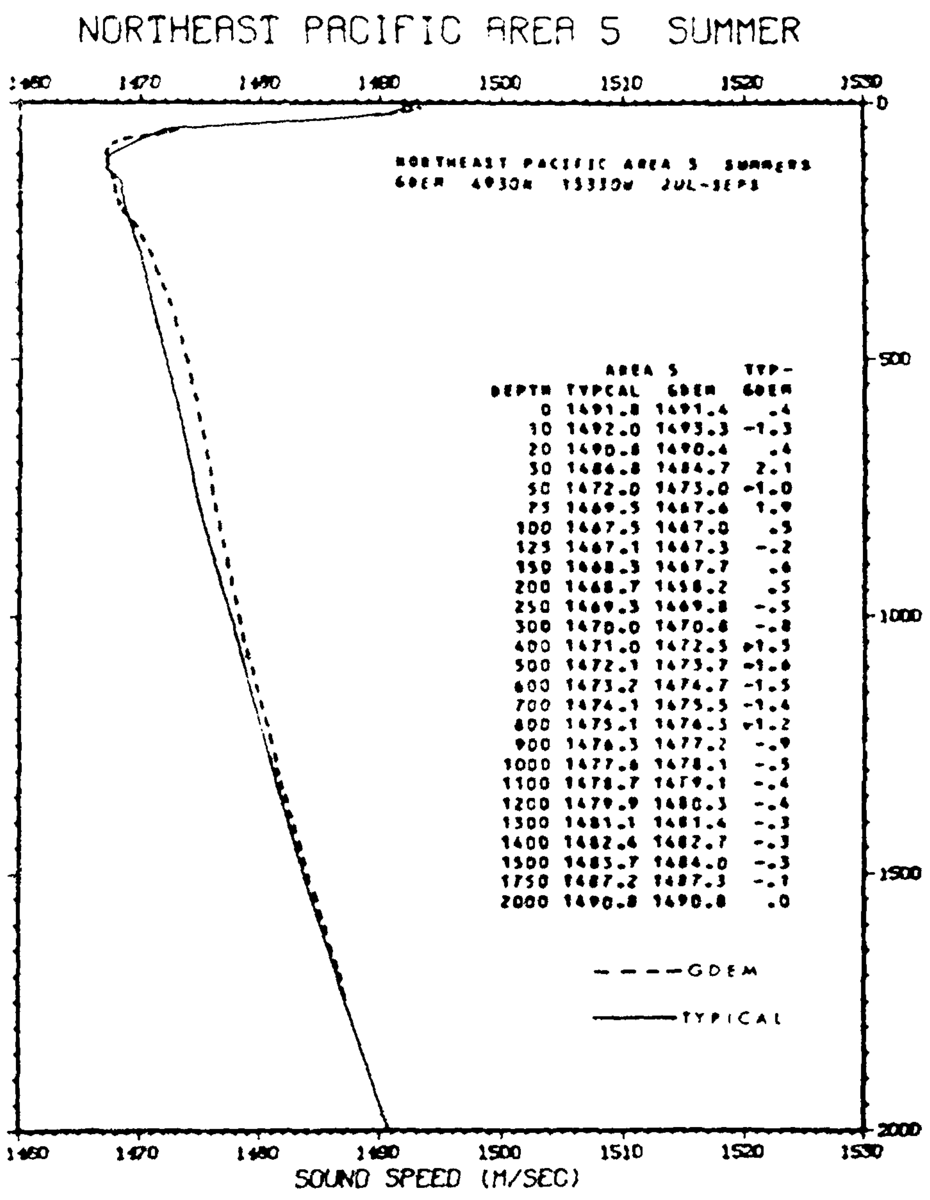
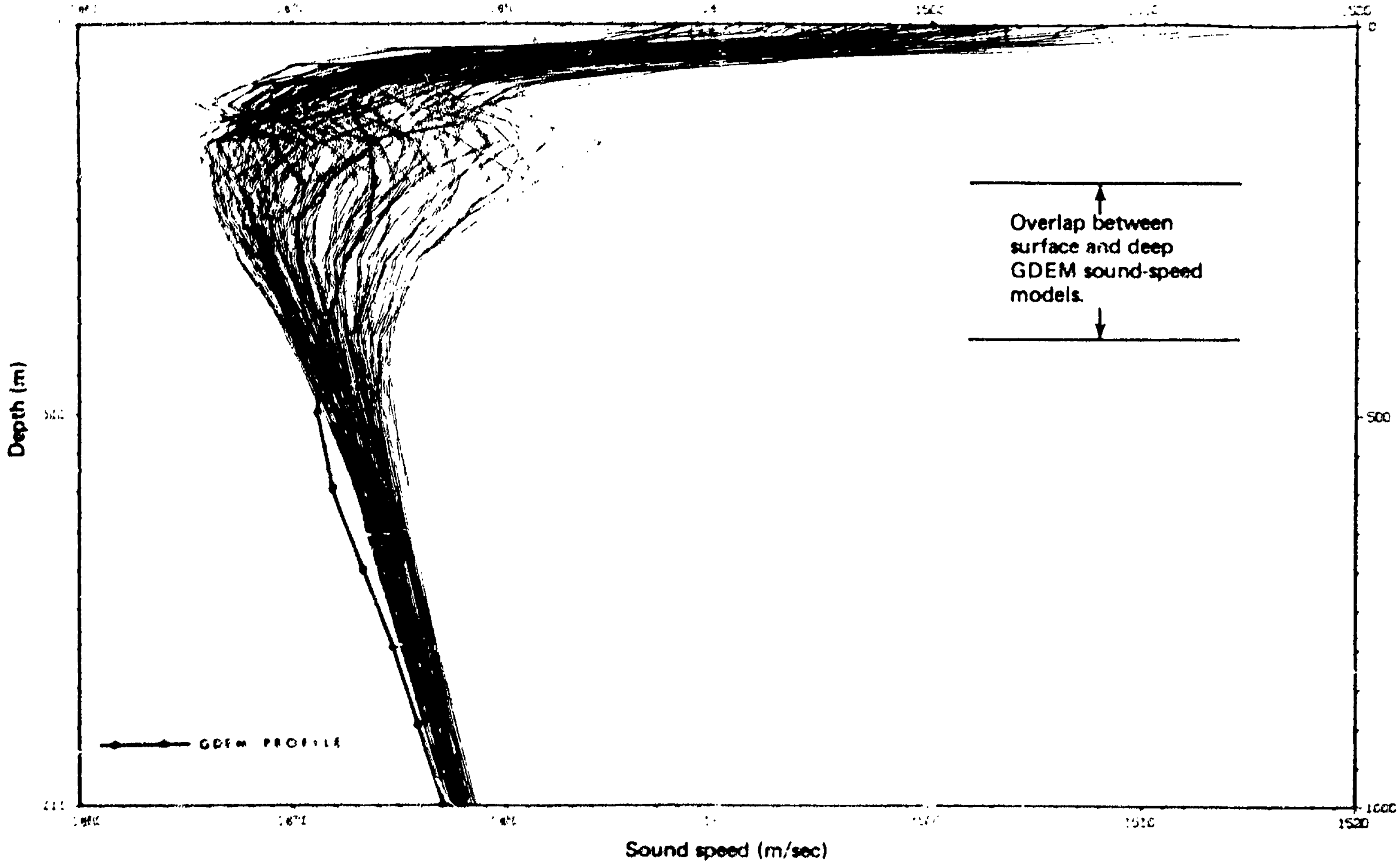


Figure 7

The profile mismatches are greatest at depths of 250-500 m in provinces 1, 3, 4, and 5. In provinces 1, 3, and 5 the model profiles, though divergent from the typical profiles, still retain the basic vertical structure of the observed data. In province 4 the problem is more serious because the model profile shifts the main channel axis depth from 300 m to 500 m. The axis depth statistics for the 140 observed summer profiles in province 4 indicate a mean depth of 253 m and a standard deviation of 109 m. Only 8 of the 140 profiles indicate a channel axis depth of 500 m, and all occur near the southern boundary of the province, 45°-46°N.

The deviation of the GDEM profile from the observed profile is vividly displayed in Fig. 8. It overplots the GDEM profile on the composite plot of all 140 observed summer profiles in province 4. The region where the surface (0-400 m) and deep (200-2450 m) GDEM sound-speed models overlap is shown for reference. The GDEM profile gradient between 300 and 500 m deviates from the majority of the observations and results in the deeper-than-expected channel axis depth.

The problem range, 250-500 m, contains the most depth points where the upper Butterworth filter model of the data merges with the middepth orthogonal polynomial model. The nature and extent of this potential problem with GDEM will require additional testing; these comparisons merely suggest that GDEM should be evaluated further to determine the quality of its output for LRAPP acoustic modeling.



Overlap between surface and deep GDEM sound-speed models.

Fig. 8--Northeast Pacific, area 4, summer

Attachment 3

INTERIM RESULTS OF GDEM [illegible]N

U.S. NAVAL OCEANOGRAPHIC OFFICE
NSTL STATION
BAY ST. LOUIS, MISSISSIPPI 39522

Code 3300:smc
27 June 1979

MEMORANDUM

From: NAVOCEANO (Code 3300/T.Davis)
To: NOSC (Joe Colborn)

Subj: Results from new temperature model (0-400M)

Encl: (1) Temperature comparison for PAC Area 4-Summer
(2) Sound Speed Comparison

1. The summary you sent me of our 17 May meeting is fine. Based on recent testing of a new temperature model containing a replacement of the quadratic tail by an exponential form, we have made a major change in our 17 May plan. Instead of proceeding directly to the Atlantic model we are rebuilding the entire Pacific sound speed model with this new temperature model. This should be completed in 6-8 weeks and be ready for your evaluation work.

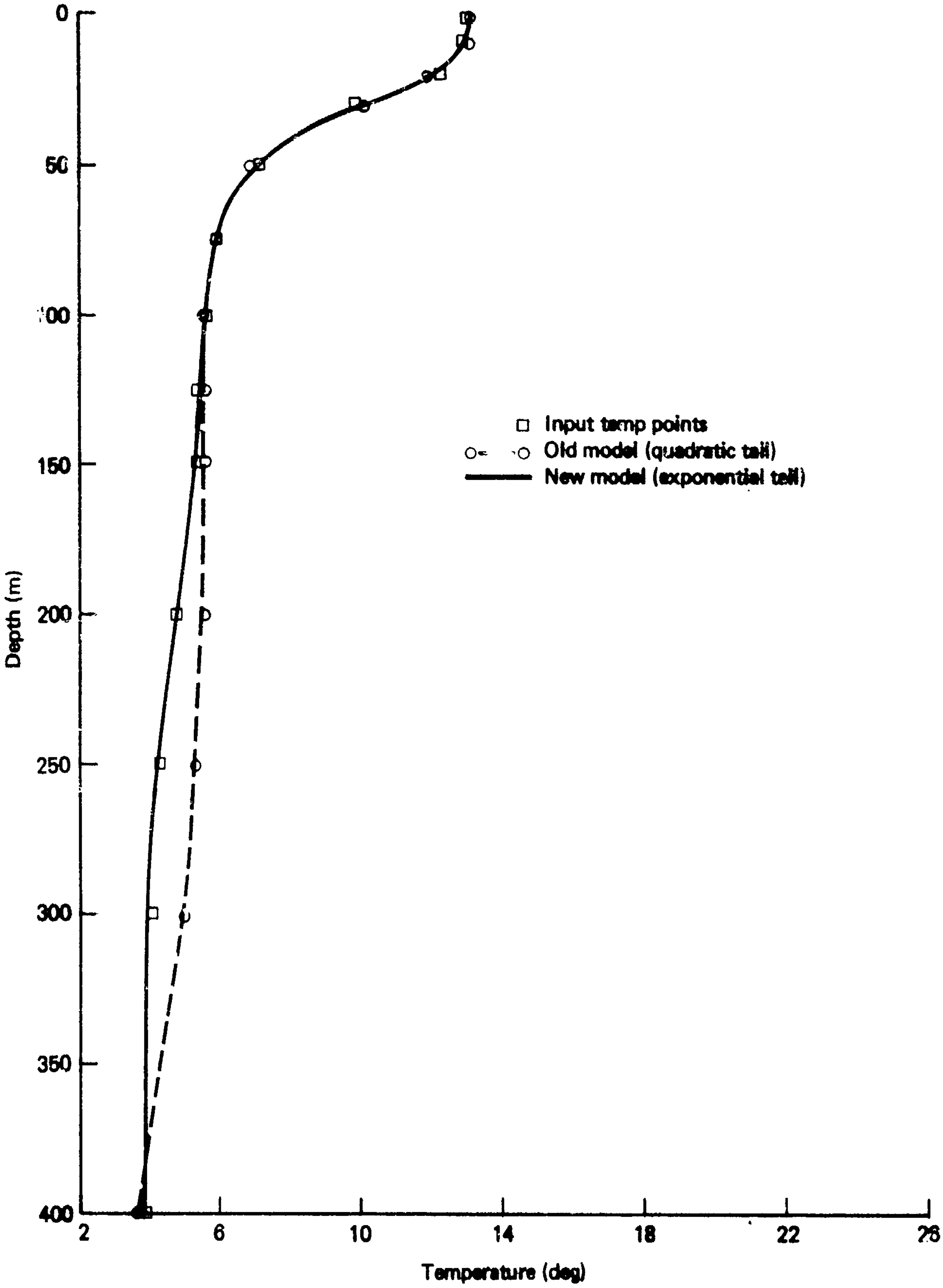
2. Enclosure (1) compares the old and new model using the temperature data you sent me for NEPAC area-4 (summer). Enclosure (2) is the equivalent sound speed using your salinities, including a plot of our middle model sound speed before the merge process. You can see that the problem with the merge which caused the middle model to be deformed to match the tail of the surface model was actually caused by the poor fit of the quadratic tail. Test results to date indicate that the exponential tail on the new temperature model will greatly improve the merge problem.

3. There is one additional change to our 17 May plan. You and John Locklin convinced me of the advantages of a separate temperature and salinity model for the middle model. We don't have time now to build these for the pacific but we plan to take this approach in the Atlantic.

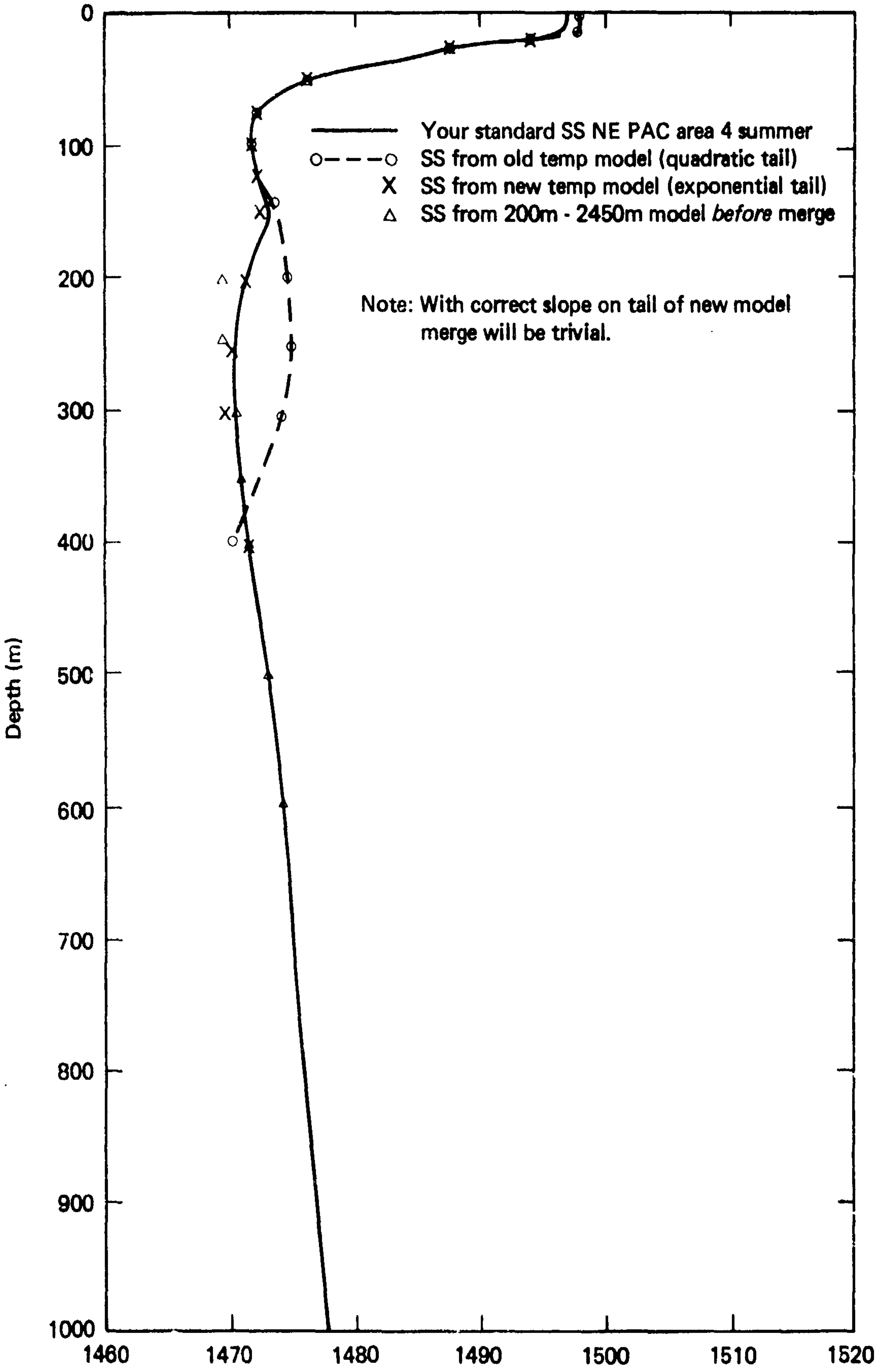
4. Thanks for sending me the Pacific listings and I'll let you know as soon as we have the new Pacific model finished.

Thomas M. Davis
TOM DAVIS

Copy to:
LCDR K.E. Evans (NORDA/Code 600)
J. Locklin, ODSI


0
50
100
150
200
250
300
350
400
Depth (m)
2
6
10
14
18
22
26
Temperature (deg)
□ Input temp points
○- -○ Old model (quadratic tail)
New model (exponential tail)

Encl (1)


Your standard SS NE PAC area 4 summer
SS from old temp model (quadratic tail)
SS from new temp model (exponential tail)
SS from 200m - 2450m model *before* merge
Note: With correct slope on tail of new model merge will be trivial.
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
1460
1470
1480
1490
1500
1510
1520
Sound speed (m/sec)

Encl (2)

Appendix D

GFDL[*]

GFDL was developed by the Geophysical Fluid Dynamics Laboratory at Princeton University. The model's objective analysis of oceanographic data derives from the iterative difference-correction method developed by Bergthörsson and Döös and modified by Cressman.[†] GDFL was designed to study the ocean's role in the global heat balance. Its output products are analyzed horizontal fields of temperature, salinity, sigma-T, and oxygen. The products are given at all standard depths[**] between the surface and 5000 m on a 1°-square grid for each month over all oceans. It is possible to compute sound-speed values and their vertical profiles at all grid points down to 5000 m from the output products. Because of its products and worldwide coverage, GFDL qualifies as a candidate for Standard Ocean.

ANALYSIS[††]

The value for each 1° square is defined as a mean representative of the square's center. The 360 × 180 grid points are located at the intersection of 1/2° lines of latitude and longitude. In the analysis, the average distance between data points (the observed means) is

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[*] This appendix is based on information provided in a letter to Daubin from Colborn, 29 March 1979, and on the following publications: P. Bergthörsson and B. Döös, "Numerical Weather Map Analysis," *Tellus*, Vol. 7, No. 3, 1955, pp. 329-340; G. P. Cressman, "An Operational Objective Analysis Scheme," *Mon. Wea. Rev.*, Vol. 87, No. 10, 1959, pp. 367-374; and S. Levitus and A. H. Oort, "Global Analysis of Oceanographic Data," *Bull. Amer. Met. Soc.*, Vol. 158, No. 12, 1977, pp. 1270-1284.

[†] See the citations in the preceding note.

[**] NODC standard depths of 0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, ..., 1500, 1750, 2000, 2500, 3000, 4000, and 5000 m. In addition, the GFDL analysis was performed at 3500 and 4500 m.

[††] This description is paraphrased with permission from Levitus and Oort, who describe the GFDL analysis and its results in detail.

computed by taking the square root of the total ocean area divided by the number of data points. An influence radius is defined as a multiple of the average distance between observation points. At the grid points coinciding with an observed mean, the difference between the mean and the first guess field is computed. At each such grid point, a correction to the first-guess value is then computed as a distance-weighted mean of all first-guess mean differences occurring within the grid point's influence radius. Mathematically, the correction factor is given by the expression

$$C_{i,j} = \sum_{s=1}^{n} W_s Q_s \Big/ \sum_{s=1}^{n} W_s \ , \tag{D.1}$$

where $C_{i,j}$ = the correction factor at point (i,j),

i,j = east-west and north-south coordinates, respectively, of a grid point,

n = the number of observations within the influence radius of point i,j,

Q_s = the difference between the first guess and the observed mean at the *sth* point in the influence area,

$W_s = \exp(-Er^2R^{-2})$, for $r \leq R$,

$W_s = 0$, for $r > R$,

r = distance of the observation from the grid point,

R = influence radius,

$E = 4$.

At each grid point, an analyzed value $G_{i,j}$ is computed as the sum of the first guess $F_{i,j}$ and the correction $C_{i,j}$ at the point. As another gross error check, if the magnitude of Q_s exceeds a prescribed limit, held constant throughout the analysis, the correction factor is not used. If there are no data points within the influence radius, the correction is zero and the analyzed value is simply the first-guess value.

Following the foregoing procedure, an analyzed field is produced at each grid point. That field becomes the new first-guess field, and the procedure is repeated until the analysis shows little change. The number of iterations required depends on the disparity between the first-guess field and the observed input data. The smaller the difference, the fewer iterations are required. After each iteration, the resulting field is smoothed with a Laplacian smoother.

The analysis scheme permits the influence radius, the error limit for the correction factor, the number of smoothings, and the intensity of smoothing to be varied with each iteration. The strategy is to begin the analysis with a large influence radius and decrease it with each iteration. Levitus and Oort were thus able to analyze progressively smaller-scale phenomena with each iteration.

EVALUATION

GFDL's basic data sources for the original analysis are outdated. The analysis of temperature was made with 1.2 million soundings composed of Nansen cast data, mechanical bathythermograph (MBT) data, and expendable bathythermograph (XBT) data, all from a pre-1973 NODC file. A new analysis is planned to include all Nansen cast/salinity temperature depth recorder (STD), XBT, and MBT data available from NODC as of June 1976.

For Standard Ocean application, GFDL's most serious flaw is the lack of attempt to preserve the vertical integrity in the parameter fields. The iterative difference-correction method is applied exclusively at horizontal levels to produce highly smoothed horizontal parameter surfaces. It ignores the unequal spatial and temporal distributions of data at successive levels. The use of recombined parameters at any grid point to recreate vertical structure distorts the gradients and obscures acoustically significant features, such as sonic layer depth and secondary channels, in the resulting sound-speed profiles.

An additional problem, recognized by Levitus and Oort, is that seasonal aliasing is produced in squares with incomplete seasonal data. Given the temporal data distribution available, aliasing would greatly distort the monthly resolution in the shallow layers. Even with three-month seasonal resolution, the structure in the final model would be questionable in some regions. Finally, the analysis extends only to a depth of 5000 m. (This is not considered to be a serious drawback, however.)

AVAILABILITY

The model is presumably completed and available, although the status of the new analysis with the revised data base is unknown. The computer code for the objective analysis was specifically developed for the GFDL computer, and the output data format may also be computer-specific. The data could be reformatted, but future updates of the model could not be produced independently if it is impractical to convert the code. Time and cost to acquire the model cannot be estimated without further investigation. Computer compatibility and the laboratory's cooperativeness are unknown factors.

SUMMARY

The GFDL model is not a suitable candidate for Standard Ocean. The objective analysis makes no attempt to preserve the integrity of the vertical structure of the sound-speed field. Computer-related difficulties prohibit updating the model in the future. GFDL's primary advantages are that the initial analysis is complete, the coverage is good, and the model is presumably available now.

Appendix E

HYDAT[*]

HYDAT (Hydro-Climatological Data Base) is a software system designed to retrieve the most-representative observed surface-to-bottom temperature and salinity profiles for a particular location and time, based on a data set within a specified radius of influence of the location. Originally developed by Ocean Data Systems, Inc., the program has undergone much modification and debugging.[†] According to Evelyn A. Hess, its operation is not yet routine nor is HYDAT ready for release.

HYDAT is intended to provide worldwide coverage over all months for which data are available. Hess believes it to be the best program for retrieving data on the southern hemisphere. For worldwide coverage, Hess considers the present data set, an older one of about 750,000 observations, inadequate. The installation of the MOODS data set at FNWC in late 1979 should improve the situation.[**] MOODS will contain $\approx 2.8 \times 10^6$ observations worldwide.

HYDAT's analysis relies on a variable, user-specified radius of influence. The area analyzed is in 1° × 1° increments; smaller grid increments are not used. Time spacing is one or two months, though smaller spacings are possible given adequate data density. Retrieval time is said to be about one minute per retrieval, depending on the size of the data set analyzed.

The program selects the mean surface-to-bottom temperature profile according to three criteria:

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[*] This appendix draws on discussions between Evelyn A. Hess (FNWC), Colborn, and Daubin held 15 March 1979 at FNWC, Monterey, California.

[†] Ocean Data Systems, Inc., *Hydroclimatological Data Retreival Program: Functional Description,* 1 November 1976.

[**] According to Lcdr. Will Rogers, FNWC, the data files for MOODS have been assembled, and MOODS is expected to be on-line shortly.

1. The profile closest to the median or mean sea surface temperature.
2. The profile closest to the median or mean temperature at 243 m (797 ft).
3. The profile closest to the mean heat content (average temperature) between 0 and 243 m.

HYDAT's analysis ignores sonic layer depth, which may therefore not be preserved. Furthermore, there is no attempt to preserve the horizontal integrity in the outputs from adjacent locations. If there are fewer than six profiles within the radius of influence, HYDAT presents all the data and lets the user decide among them. HYDAT can distinguish and identify two water masses within the same radius of influence, unless their temperature profiles cross or converge at depth. But more than two water masses are too much for HYDAT's analysis. The subroutine Single-SAL selects the most typical salinity profile. In the older climatology salinity data are less abundant than temperature data.

SUMMARY

HYDAT is an unsuitable Standard Ocean candidate for the following reasons:

1. The analysis may fail to preserve sonic layer depth and horizontal continuity with adjacent areas.
2. The code is not yet ready for release; an experienced operator is required to run the model.
3. The model relies on an older, less reliable climatology.
4. The model may not retrieve representative profiles in areas or during periods of sparse data.

Appendix F

ICAPS[*]

The Integrated Command Antisubmarine Warfare Prediction System (ICAPS) is an operational oceanographic data analysis system developed by the Naval Oceanographic Office (NAVOCEANO). It is being used by units in the fleet for sonar range prediction. The system can be run on a Univac 1108, Nova 800, or IBM 360 computer.

ICAPS merges observed XBT profiles with the appropriate deep temperature profiles through a temperature/salinity analysis using historic salinities (water-mass identification). Salinities above 400 m can be adjusted to maintain a nonnegative local density gradient in areas affected by temperature inversions. The operator can override the system if he disagrees with a decision. The system contains a library of typical observed XBT casts and known seasonal water-mass characteristics for the northern hemisphere and the Indian Ocean to 20°S.

Using the merged temperature and historic salinity profiles, ICAPS generates the local sound-speed profile from the surface to the bottom. Then it computes the acoustic eigen-rays and propagation losses in the immediate vicinity using the FACT algorithm. In the latter computations it is assumed that the water mass is uniform near the XBT cast. ICAPS cannot yet predict the range-dependent sound-speed structure from a given point, but W. R. Floyd expects a predictive capability to be developed sometime in the future.

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[*] This appendix draws on discussions between William R. Floyd (NAVOCEANO), Paul Moersdorf (NAVOCEANO), Colborn, and Daubin held 8 March 1979 at NAVOCEANO, Bay St. Louis, Mississippi, and on the following publications: Alvan Fisher, Jr., *The ICAPS Water Mass History File*, NAVOCEANO, NOORP-19, May 1978, and idem, *Oceanographic Analysis Manual for On-Scene Prediction Systems*, NAVOCEANO, NOORP-20, May 1978.

METHODOLOGY

The following paragraphs describe how ICAPS selects the water-mass characteristics and merges the temperature profiles.[*]

Two assumptions were made in developing the ICAPS historic water-mass file: (1) near-surface water masses can be uniquely identified by thermohaline characteristics, and (2) the thermal characteristics of neighboring water masses are different enough to permit reliable identification from an expendable bathythermograph (XBT) trace alone. After identification of the applicable deep history, the temperature values of the input trace are merged with deep temperatures using an equation of the form

$$T_i = TH_i + K_i(K_{i-1}\Delta T) , \qquad (F.1)$$

where T_i and TH_i are, respectively, estimated and historical temperatures at depth i; K is a weighting factor; and ΔT is the difference between the temperature at the bottom of the XBT trace and the interpolated historical temperature at the same depth. The weighting factor,[†] developed from empirical solution for a set of historical data, is determined as a function of the depth increment between points $(D_i - D_{i-1})$:

$$K_i = 0.835^{(D_i-D_{i-1})/100} . \qquad (F.2)$$

At the first synthesized temperature value ($i = 1$), K_{i-1} equals unity.

Because classical oceanographic literature provides few guidelines for water-mass identification, it was decided that the most objective way of determining water-mass characteristics within a given area was to review original oceanographic data. Two NAVOCEANO data files were

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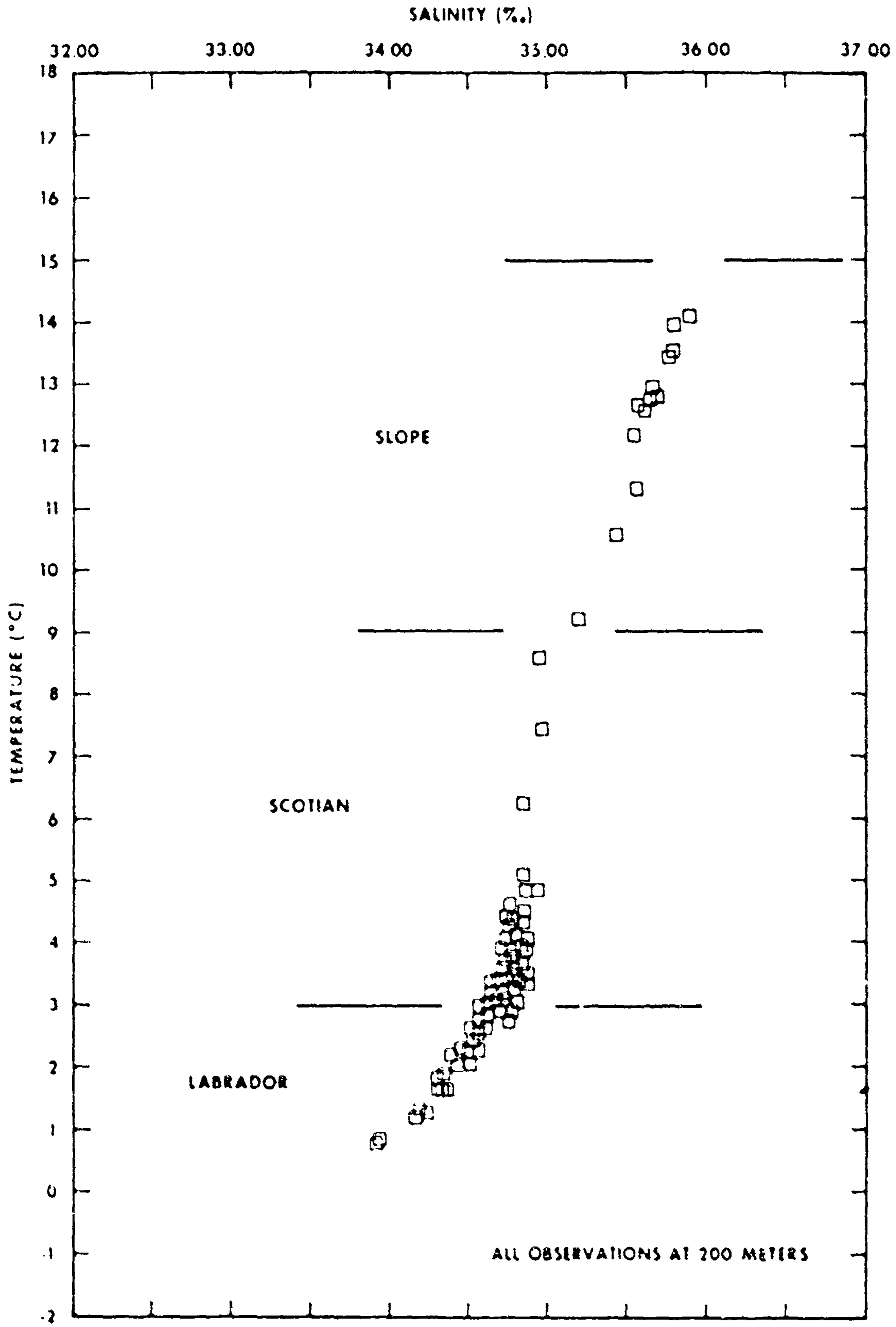
[*] This subsection is paraphrased from Fisher, *The ICAPS Water Mass History File*, pp. 1-10, with permission.

[†] Later evaluation of the merge showed that a constant of 0.790 created a more realistic merge in the Mediterranean Sea. The value of 0.835 was retained for all other areas.

available. (1) An oceanographic station data file of approximately 491,000 observations compiled by the National Oceanographic Data Center (NODC) provided temperature and salinity data at 32 standard depths between the surface and 7000 m. (2) An XBT file of approximately 218,000 observations from three sources (NAVOCEANO, NODC, and FNWC) provided temperature data at each flexure point over the depth range of the instrument (as deep as 760 m). The following procedure was used to determine water-mass characteristics in the near-surface layer (0-400 m):

1. The classical literature was searched for applicable descriptions. For example, the northern edge of the Gulf Stream is frequently delineated by the 15°C isotherm at 200 m.
2. The ocean station data file was used to provide annual composite statistics (mean, standard deviation, number of observations) at each standard depth using all available data within the area of interest. Plots of the distribution of temperature versus salinity at 200 and 400 m helped determine the number of water masses present and the thermohaline variability within each. Figure F.1 shows a plot of temperature versus salinity at 200 m in an area where the cold Labrador current meets the warmer North Atlantic drift. The presence of water masses with specific thermohaline characteristics is clearly recognizable, and tentative water-mass classification has been made. The 200 m level was found to be a good depth for classification since it is too deep for diurnal and seasonal influences yet within the depth range of XBT probes. The XBT file provided statistical data and histograms for temperature and temperature gradients at preselected depths to supplement the ocean station data.
3. Flexure points in the temperature versus salinity (T-S) plot shown in Fig. F.1 clearly defined water-mass criteria in areas where different water masses existed in close proximity. Considerable temperature variability also occurred in areas containing a single water mass, probably a result of dynamic



Source: Fisher, *The ICNAF Water Mass History File*, p. 3 (used by permission).

Fig. F.1--Distribution of temperature versus salinity events such as upwelling. Where variability of this nature was observed, two classifications ("warm" and "cold") were made to provide a better merge between XBT trace and history.

4. Temperature ranges (filters) at 200 m were developed to distinguish adjacent water masses based on information provided in the previous steps. If adjacent water masses had similar temperature ranges at 200 m, they were differentiated by examining the temperature gradient between 200 and 300 m. For example, both the Gulf Stream and the Sargasso Sea are characterized by a temperature range of 15° to 25°C at 200 m. Analysis of a near-isothermal layer of 18°C water extending from the bottom of the seasonal thermocline to over 300 m deep in the Sargasso water far from the Gulf Stream showed that 95 percent of the observations had a temperature gradient between 0.0°C/100 m and -1.6°C/100 m. Thus, in the region of the Gulf Stream, the gradient -1.6°C/100 m at the 200-300 m level is used to differentiate Gulf Stream water from Sargasso water.
5. Mean seasonal temperature and salinity values were then determined for each depth and water mass (Table F.1). Where the data were not deep enough, temperature and salinity were extrapolated to the bottom by comparison with neighboring profiles. Inconsistencies in the data--such as a temperature inversion at depths below 200 m--were examined to determine if they were a result of statistical processing, data distribution, or bad data.
6. A quality control check was made by plotting the seasonal data on a single plot of temperature versus salinity (Fig. F.2). That procedure immediately reveals inconsistencies in the data: temperature errors are indicated by vertical spikes, salinity errors by horizontal spikes, and depth errors by skewed spikes. Where data were obviously incorrect, the plot was smoothed to conform with surrounding data. A second quality control check was made by visually inspecting the seasonal traces of temperature and salinity versus depth. Again, discrepancies were smoothed after comparison with neighboring traces.

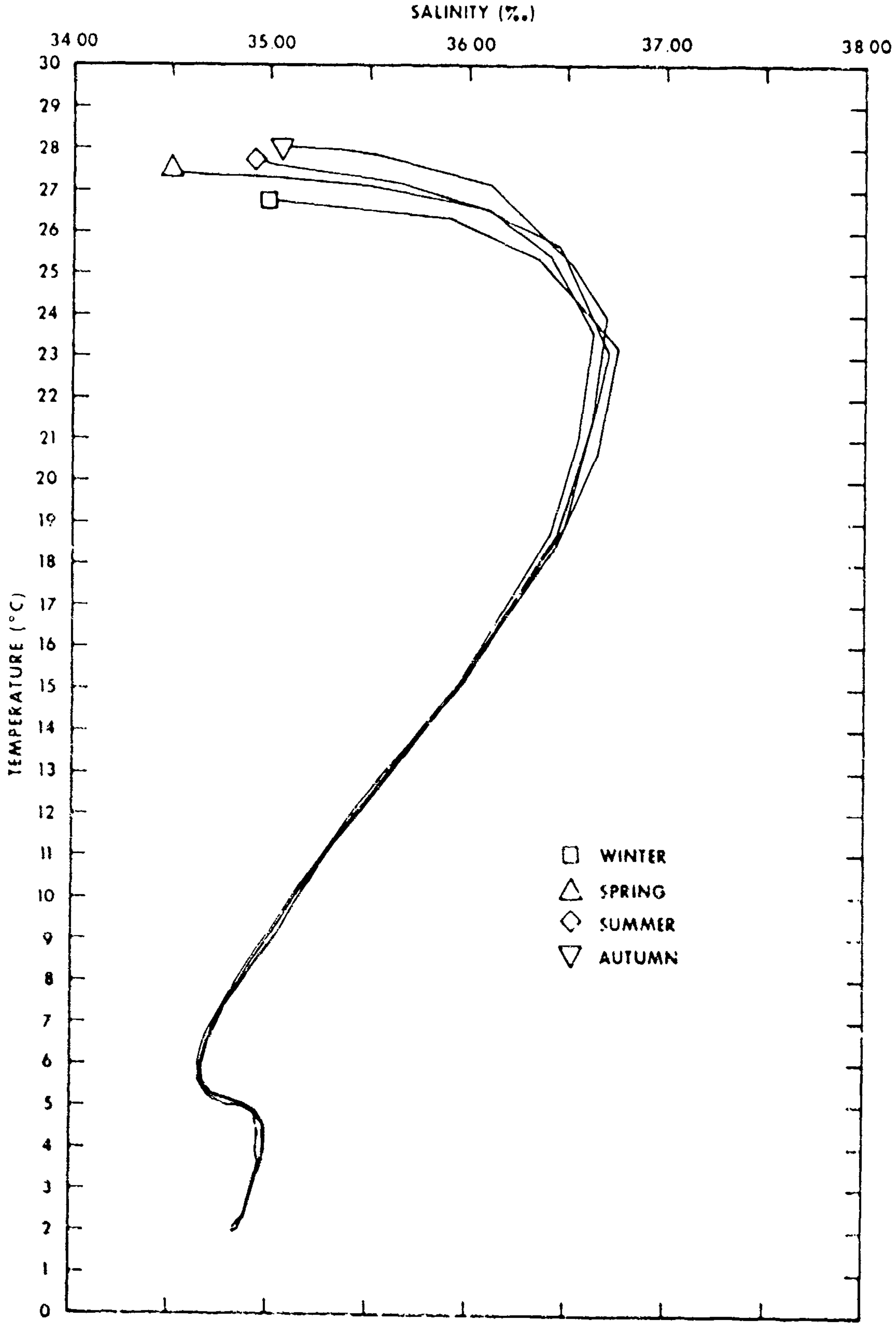
Table F.1

TEMPERATURE AND SALINITY AT STANDARD DEPTHS IN SLOPE WATER

Standard Depth	Temperature (°C) Mean	Temperature (°C) Standard Deviation	Temperature (°C) Number of Observations	Salinity (‰) Mean	Salinity (‰) Standard Deviation	Salinity (‰) Number of Observations
0	23.77	2.28	676	34.34	1.10	684
10	23.10	2.65	682	34.55	.97	680
20	21.72	3.70	682	34.84	.83	680
30	19.42	4.36	683	34.96	.83	679
50	15.87	4.17	683	35.14	.76	678
75	14.49	2.86	683	35.41	.55	678
100	13.78	2.04	683	35.54	.38	678
125	13.16	1.57	684	35.54	.28	678
150	12.54	1.34	684	35.51	.22	678
200	11.21	1.24	684	35.38	.17	676
250	9.86	1.23	684	35.24	.15	674
300	8.68	1.25	682	35.14	.13	674
400	6.87	1.10	582	35.03	.10	575
500	5.67	.79	551	34.99	.06	546
600	5.03	.52	529	34.98	.05	525
700	4.67	.32	518	34.98	.04	514
800	4.43	.24	473	34.97	.03	471
900	4.27	.20	438	34.97	.03	436
1000	4.13	.17	393	34.96	.03	386
1100	4.02	.15	350	34.96	.04	345
1200	3.92	.13	330	34.96	.04	324
1300	3.85	.12	322	34.96	.04	316
1400	3.78	.12	319	34.95	.04	313
1500	3.72	.12	315	34.95	.04	311
1750	3.56	.09	270	34.95	.04	264
2000	3.41	.09	239	34.95	.04	233
2500	3.06	.11	160	34.94	.03	154
3000	2.59	.16	89	34.92	.03	84
4000	2.26	.07	41	34.90	.02	38

SOURCE: Adapted from Fisher, *The ICAPS Water Mass History File*, p. 5 (used by permission).

NOTE: Slope water characteristics are as follows: location, 35°-42°N, 60°-76°W; season, summer; temperature range, 9°-15°C; salinity range, 30-40 ‰.



SOURCE: Fisher, *The ICAPS Water Mass History File*, p. 6 (used by permission).

Fig. F.2--Seasonal plots of temperature versus salinity

The water-mass file has been segmented to permit installation in computers of various storage capacity. For example, the North Atlantic is divided into areas A though E, the North Pacific A through G, and the Indian Ocean A through D. Each area is further divided into regions of similar oceanographic properties, the lowest denominator being a 1° rectangle. A region may have as many as five water masses but is normally limited to two or three. Historical data are provided by season. In most regions winter is January through March. In the Indian Ocean, however, the winter monsoon is October through March; summer monsoon, April through September. Given the geographic position, data from an XBT trace, and season, the program will automatically select the proper water-mass history for the merge.

EVALUATION

For several reasons, ICAPS is an attractive candidate for Standard Ocean:

1. The system is highly automated and can be operated successfully by a nonoceanographer.
2. It is operational and available.
3. It can differentiate and identify water masses.

W. R. Floyd considers ICAPS a reliable system in the North Atlantic, less so in the North Pacific.

Other features of ICAPS make it unsuitable for Standard Ocean:

1. ICAPS cannot make range-dependent predictions of sound speed. It assumes a uniform environment in the vicinity of the XBT cast input. Therefore, it will not function well near fronts or in highly variable regions.
2. The system requires XBT data as input.
3. The identification of water mass and subsequent extension of the XBT profile to the bottom may not be reliable in areas where the deep climatology (>400 m) varies significantly (e.g., the eastern North Atlantic near the Mediterranean

outflow). Having made no assessment of ICAPS' performance, the Standard Ocean Evaluation Group is unsure of the seriousness of the foregoing disadvantage.

Appendix G

ODSI[*]

Ocean Data Systems, Inc. (ODSI) proposes to develop an environmental data retrieval system to be used as Standard Ocean. Captain P. M. Wolff is to direct five analysts in the effort. Captain Wolff plans to base the model on similar work done by ODSI for the Department of Energy.[†] For each oceanic square, the model will contain the monthly most probable, minimum and maximum temperature, salinity, sound-speed profile, and sonic layer depth. ("Most probable" refers to typical oceanographic conditions in an area; it is not an average or a mean of local observations, which might portray an environment that would never be observed.) Profiles will extend from the surface to the greatest depth in the square. Squares will vary in size depending on local complexity; typically, they will be 1° × 1°. In addition to the profiles, ODSI would provide the following oceanographic information for each square:

- Current and frontal boundaries.
- The presence of strong bottom currents, upwelling, and eddies.
- Shelf phenomera (not defined) and shelf boundaries.
- σ_T profiles (minimum, maximum, and most probable).
- Basin sill depths.
- Discrete profiles for two water masses, if present (how they would be differentiated is unexplained[**]).

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[*] This appendix draws on discussions between Capt. Paul M. Wolff (ODSI), Colborn, Daubin, and Hashimoto held 16 March 1979 at Ocean Data Systems, Inc., Monterey, California.

[†] P. M. Wolff, *Temperature Variability at Three OTEC Sites*, Ocean Data Systems, Inc., July 1978; Ocean Data Systems, Inc., and U.S. Department of Energy, *OTEC Thermal Resource Report for Western Gulf of Mexico*, TID-27949, October 1977; idem, *OTEC Thermal Resource Report for Central Gulf of Mexico*, TID-27951, n.d.

[**] Appendixes E and F describe algorithms for identifying water masses.

The data would be arranged in tables, with eddies, currents, and the like represented by code.

The data to be used in deriving the model will come from the sources in ODSI's extensive in-house data library. Three files will be maintained for the model's preparation.

	Data	Source
File 1.	Nansen casts STDs CTDs[*]	NODC
File 2.	XBTs AXBTs[†]	NODC (50%) FNWC (50%)
File 3.	MBTs	NODC

File 1 will take precedence over files 2 and 3 when sufficient data are available. File 3 will be used only in holidays where no data from files 1 and 2 are available. If data are unavailable for certain areas from any file, values will be extrapolated from adjacent areas. Captain Wolff will avoid analyzing adjacent data sets containing data from different time periods. Rather, he will attempt to analyze what might be called temporally averaged data sets. The space scale will be appropriate to the local situation. For example, in areas near frontal boundaries such as the Gulf Stream, grid spacing would be much finer (<1° × 1°) than in the Sargasso Sea, where little spatial and temporal variability is expected.

Boundaries and boundary widths for currents and fronts would be used to set boundary conditions, which would be moved to match observed conditions in the model's synoptic version. The model would preserve horizontal and vertical gradients.

EVALUATION

An impressive amount and variety of data are to be included in the proposed ODSI model--even exceeding the base requirements for

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[*] Conductivity/temperature/depth instrument readings.

[†] Airborne expendable bathythermograph traces.

Standard Ocean in some respects. As ODSI remains conceptual and untested, however, the Standard Ocean Evaluation Group has no way of judging the quality of the model's output products. Running an analysis of even a small area for preliminary evaluation would entail substantial start-up costs. Furthermore, it is doubtful that the model can be satisfactorily completed for the estimated cost ($180,000) and within the estimated time (18 months). Other candidates such as GDEM and AUTO-OCEAN, while lacking the quantity of output products of ODSI, are available for evaluation now and should be less expensive to acquire. For those reasons, we recommend against adopting the ODSI model for Standard Ocean.

Appendix H

SIMAS[*]

The Sonar In-Situ Mode Assessment System (SIMAS) sound-speed data file was developed by the Naval Underwater Systems Center (NUSC), New London. Its purpose is to indicate the sound-speed structure below 366 m. extending an observed XBT-derived sound-speed profile. The basic file contains annual sound-speed profiles from 366 m to the bottom for 70 so-called homogeneous areas in the North Atlantic, 69 areas in the North Pacific, and 50 areas in the Indian Ocean.[†] Coverage for the Atlantic and Pacific extends from 63°N to 10°S; Indian Ocean coverage extends from the coast to 50°S. The data have been digitized geographically to a presumed resolution of at least 1° latitude and 1° longitude. In addition, monthly best-guess sound-speed profiles are available for the upper 366 m, although they may not be in a spatially digitized format. The complete profiles are available in atlas reference charts by area. The program and data are computerized for shipboard operation. The system resembles ICAPS (Appendix F) in purpose, except that ICAPS can identify the local water mass whereas SIMAS depends on fixed sound-speed province boundaries.

EVALUATION

The SIMAS analysis is based on the original NODC Hansen cast data base available before 1976, when the original analysis was reported. The data were edited by keeping only the most recent observations while trying to retain spatial and temporal coverage. Through a subjective analysis, standard profiles and area boundaries were selected. After analysis the data set was reduced to only 0.1 percent of the

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[*] This appendix draws on information in a letter to Daubin from Colborn, 29 March 1979.

[†] Eugene M. Podeszwa, *Sound Speed Profile for the North Pacific Ocean*, Naval Underwater Systems Center, TD-5271, 2 February 1976; idem, *Sound Speed Profiles for the North Atlantic Ocean*, Naval Underwater Systems Center, TD-5447, 20 October 1976; idem, *Sound Speed Profiles for the Indian Ocean*, Naval Underwater Systems Center, TD-5555, 11 December 1976.

original observations. Vertical smoothing of the data was performed. Horizontal smoothing was used to produce a single structure for the entire North Pacific below 2134 m.

It is difficult to evaluate the technical quality of the sound-speed profiles because of the subjectivity of the analysis. We can, however, point out defects in the homogeneous sound-speed area format designed to provide a single profile for a given location and month. That structure is not a true sound-speed field; it does not have realistic horizontal gradient characteristics; and it cannot be reliably used to produce range-dependent model inputs.

The availability of SIMAS is not known. However, the analysis is complete and published in atlas form.* The time and cost to acquire the digital data file would depend on its compatibility with the computer format of the LRAPP data bank. Acquisition might be accomplished in a fairly short time and at reasonable cost.

SUMMARY

The SIMAS data file is not a suitable Standard Ocean candidate because it has not been developed to produce a sound-speed field with horizontal continuity. Extensive testing would be needed to resolve questions of its technical quality. The model's main advantage is its presumed availability now.

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*See the three Podeszwa reports cited above.

BIBLIOGRAPHY

Audet, J. J., Jr., and G. E. Vega, *AESD Sound-Speed Profile Retrieval System (RSVP),* Acoustic Environment Support Detachment, ONR, AESD Technical Note TN-74-03, October 1974.

Audet, J. J., Jr., *Seasonal Critical Depth Charts and Deep Sound Channel Interference for the Ocean and Seas of the Northern Hemisphere,* Acoustic Environmental Support Detachment, ONR, AESD Technical Note TN-75-02, April 1975.

Bergthörsson, P., and B. Döös, "Numerical Weather Map Analysis," *Tellus,* Vol. 7, No. 3, 1955, pp. 329-340.

Colborn, J. G., and J. D. Pugh, *A Procedure for Selection of Typical Sound Speed Profiles,* Naval Undersea Center, NUC TN 1006, May 1973.

Cressman, G. P., "An Operational Objective Analysis Scheme," *Mon. Wea. Rev.,* Vol. 87, No. 10, 1959, pp. 367-374.

Fisher, Alvan, Jr., *The ICAPS Water Mass History File,* NAVOCEANO, NOORP-19, May 1978.

-----, *Oceanographic Analysis Manual for On-Scene Prediction Systems,* NAVOCEANO, NOORP-20, May 1978.

Leroy, C. C., "Development of Simple Equations for Accurate and More Realistic Calculation of the Speed of Sound in Seawater," *J. Acoust. Soc. Am.,* Vol. 46, 1969, pp. 216-226.

Levitus, S., and A. H. Oort, "Global Analysis of Oceanographic Data," *Bull. Amer. Met. Soc.,* Vol. 158, No. 12, 1977, pp. 1270-1284.

Locklin, J., et al., *LRAPP Objective Analysis: A Review of Objective Analysis Schemes for the LRAPP Data Management Program,* LRAPP, 20 March 1979.

"LRAPP Objective Analysis," Ocean Data Systems, Inc., 20 March 1979, unpublished report.

Mamayev, O. I., *Temperature-Salinity Analysis of World Ocean Waters,* Elsevier Oceanography Series, Vol. 11, Elsevier Press, Amsterdam, The Netherlands, 1975.

Ocean Data Systems, Inc., *Hydroclimatological Data Retrieval Program: Functional Description,* 1 November 1976.

Ocean Data Systems, Inc., and U.S. Department of Energy, *OTEC Thermal Resource Report for Central Gulf of Mexico,* TID-27951, n.d.

-----, *OTEC Thermal Resource Report for Western Gulf of Mexico,* TID-27949, October 1977.

Podeszwa, Eugene M., *Sound Speed Profiles for the Indian Ocean,* Naval Underwater Systems Center, TD-5555, 11 December 1976.

-----, *Sound Speed Profiles for the North Atlantic Ocean*, Naval Underwater Systems Center, TD-5447, 20 October 1976.

-----, *Sound Speed Profiles for the North Pacific Ocean*, Naval Underwater Systems Center, TD-5271, 2 February 1976.

Roden, G. I., "On North Pacific Temperature, Salinity, Sound Velocity and Density Fronts and Their Relation to the Wind and Energy Flux Fields," *J. Phys. Oceano.*, Vol. 5, No. 4, 1975, pp. 557-571.

-----, "Temperature and Salinity Fronts at the Boundaries of the Subarctic-Subtropical Transition Zone in the Western Pacific," *J. Geophys. Res.*, Vol. 77, No. 36, 1972, pp. 7175-7187.

U.S. Naval Weather Service Numerical Environmental Products Manual, NAVAIR 50-IG-522, 1 June 1975.

Wolff, P. M., *Temperature Variability at Three OTEC Sites*, Ocean Data Systems, Inc., July 1978.

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TO: Distribution

14 March 1980

FROM: Scott C. Daubin, Jr.
Coordinator, Standard
Ocean Evaluation Group
SEAS Modeling Program

SUBJECT: Evaluation of Standard Ocean Candidates:
Forwarding of Report

ENCL.: PSR Report 922, *Evaluation of Standard Ocean Candidates*, March 1980

1. The Long Range Acoustic Propagation Project (LRAPP) of the Naval Ocean Research and Development Activity (NORDA) has sponsored a search for an oceanographic data retrieval system, to be installed as Standard Ocean in the LRAPP data bank. (LRAPP is now entitled the Surveillance Environmental Acoustic (SEAS) Project.) Standard Ocean's primary purpose will be to provide range-dependent sound-speed profiles for input to NORDA's numerical acoustic models. Standard Ocean will also support the analysis of environmental data collected during exercises at sea. Eight existing or proposed candidate systems were assessed by the Standard Ocean Evaluation Group between January and August of 1979. Each candidate was rated for its ability to meet LRAPP's requirements for accuracy, ease of use, speed, availability, and cost. Two of the eight candidates, AUTO-OCEAN and GDEM, were found to meet or exceed most Standard Ocean criteria.

2. The enclosed report by the Standard Ocean Evaluation Group details the results of its assessment. The report is authorized by the manager, SEAS modeling program.

Enclosure: As noted
Distribution: Printed at end of report

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
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IN REPLY REFER TO:

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31 Jan 06

MEMORANDUM FOR DISTRIBUTION LIST

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

> Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.
>
> DISTRIBUTION STATEMENT A: Approved for Public Release; Distribution is unlimited.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

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By direction

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

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Declassified LRAPP Documents

Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IVB. DATA POINTS 10, 11 AND 12 RAW DATA	Sanders Associates, Inc.	790109	ADC017579	U
ARLTR7924	Mitchell, S. K., et al.	ANALYSIS OF ACOUSTIC BOTTOM INTERACTION IN BEARING STAKE (U)	University of Texas, Applied Research Laboratories	790223	ADE001369; NS; ND	U
TIU1886502F	Eichenberger, D.	REPORT FOR CHURCH STROKE II OCEANOGRAPHIC SERVICES	Texas Instruments, Inc.	790326	ADB036751; ND	U
Unavailable	Unavailable	FINAL REPORT, 1 NOVEMBER 1976-31 DECEMBER 1978	Xonics, Inc.	790430	ADB037987	U
Unavailable	Mitchell, T. M.	PREMOBILIZATION OF R/V INDIAN SEAL	Texas Instruments, Inc.	790531	ADB039703	U
Unavailable	Hays, E. E.	ACODAC AMBIENT NOISE PROGRAM	Woods Hole Oceanographic Institution	790601	ADB040404	U
LRAPPR79029	Unavailable	INTRODUCTION TO THE LRAPP ENVIRONMENTAL-ACOUSTIC DATA BANK (U)	Naval Ocean R&D Activity	790601	ADB041066; NS	U
USRD NO. 4807	Unavailable	MEASUREMENTS ON AQUADYNE MODEL AQ-1 ELEMENTS FOR THE UPGRADED LAMBDA ARRAY	Naval Research Laboratory	790802	ND	U
Unavailable	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA ANALYSIS	University of Texas, Applied Research Laboratories	790814	ADA073876	U
BR U0048-9C2	Unavailable	TAP III FINAL REPORT (U)	Bunker-Ramo Corp. Electronic Systems Division	790901	ND	U
ORITR1245	Moses, E. J.	OPTIONS, REQUIREMENTS, AND RECOMMENDATIONS FOR AN LRAPP ACOUSTIC ARRAY PERFORMANCE MODEL (U)	ORI, Inc.	790917	NS; ND	U
Uavailable	Colborn, J. G., et al.	EVALUATION OF STANDARD OCEAN CANDIDATES	Pacific-Sierra Research Corp,	800301	ADA087304	U
Unavailable	Kirby, W. D.	ENVIRONMENTAL ACOUSTIC SUPPORT FOR FLEET OPERATIONS AND NATO	Science Applications, Inc.	801112	ADB052623	U
Unavailable	Unavailable	SUMMARY OF ENVIRONMENTAL ACOUSTIC MEASUREMENTS, MODELING AND ANALYSIS	University of Texas, Applied Research Laboratories	801215	ADB053770	U
Unavailable	Renner, W. W., et al.	SURFACE DUCT, ROUGH SURFACE SCATTERING, AND CUSPED CAUSTIC IMPROVEMENTS FOR FACT	Science Applications, Inc.	810301	ADA126250	U
Unavailable	Wilson, J. H.	WIND-GENERATED NOISE MODELING	Science Applications, Inc.	810401	ADA190143	U
Unavailable	Goit, E. H.	TOWED ARRAY PERFORMANCE PREDICTION SYSTEM - VERSION 1.2	Science Applications, Inc.	810701	ADB059397	U
3	Unavailable	FINAL REPORT	University of Texas, Applied Research Laboratories	810721	ND	U