

AD No. 23482
ASTIA FILE COPY

The A. & M. College of Texas

DEPARTMENT OF OCEANOGRAPHY



OCEANOGRAPHIC SURVEY OF THE GULF OF MEXICO

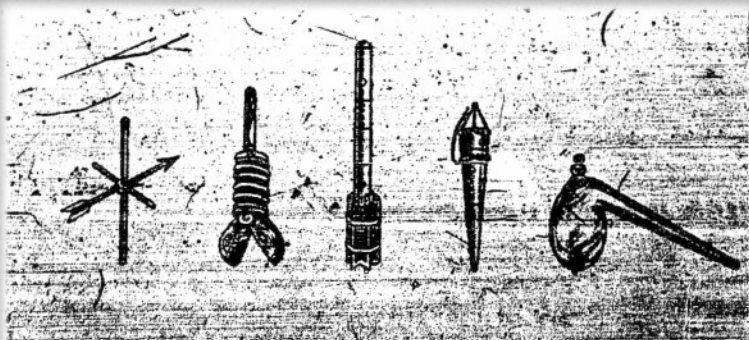
Office of Naval Research
Contract N7 onr-48702
Bureau of Ships
NE 120219-5

Navy Department
Project NR 083 036
Technical Report No. 11
January 1954

Depth of The Motionless Layer
In The Gulf of Mexico

Richard M. Adams

Research Conducted through the
Texas A. & M. Research Foundation
COLLEGE STATION, TEXAS



THE AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
Department of Oceanography
College Station, Texas

Research conducted through the
Texas A. & M. Research Foundation

Project 24

DEPTH OF THE MOTIONLESS LAYER
IN THE GULF OF MEXICO

Project 24 is an Oceanographic Survey of the Gulf of Mexico sponsored by the Office of Naval Research (Project NR 083 036, Contract N7onr-487 T.O. II) and the Bureau of Ships (NE 120219-5). The work reported herein is of a preliminary nature and the results are not necessarily in final form.

Report prepared January 6, 1954
by
Richard M. Adams

Dale F. Leipper
Project Supervisor

TABLE OF CONTENTS

	Page
Abstract	
Introduction.....	1
Source of Data.....	1
Defant's Method.....	1
Hidaka's Method.....	3
Comparison of Results.....	4
Plans for Future Work.....	5
Acknowledgements.....	6
Figures	
Distribution List	

DEPTH OF THE MOTIONLESS LAYER
IN THE GULF OF MEXICO

Richard M. Adams

Abstract

The methods of Defant and Hidaka have been used in this study of the depth of the motionless layer in the Gulf of Mexico. Data used in the study were obtained on Cruises 1, 2 and 3 of the U. S. Fish and Wildlife Service vessel ALASKA. The results of the two methods are shown pictorially in order to facilitate comparison. A comparison is also made with results obtained by Dietrich who employed the method of depth of minimum oxygen content.

DEPTH OF THE MOTIONLESS LAYER
IN THE GULF OF MEXICO

1. Introduction. In the following report, the results of two methods for determining the depth of no motion in the Gulf of Mexico are presented. No effort is made at this time to support or criticize either method since it is felt that the amount of data upon which these studies were based is too small to warrant the drawing of definite conclusions. However, comparison of the results of these methods is of interest.
2. Source of Data. In 1951, personnel of this project working in cooperation with the U. S. Fish and Wildlife Service of Galveston, Texas, completed three cruises in the Gulf of Mexico using the Fish and Wildlife vessel ALASKA. These cruises were planned to give a complete coverage of the Gulf. The three cruise plans, showing stations occupied successfully, are shown in Figure 1. Stations were normally spaced at forty mile intervals with exceptions being in the Straits of Florida and the Yucatan Channel where they were spaced at approximately twenty mile intervals.

Cruise 1 included the central Gulf, Straits of Florida and the Yucatan Channel. Cruise 2 covered the western Gulf from Longitude $92^{\circ}W$ to the Texas-Mexico coast. Unfortunately, a period of rough weather caused the omission of four important stations along Longitude $92^{\circ}W$. Cruise 3 covered the northeastern portion of the Gulf.
3. Defant's Method. Defant has shown (1941) that in the Atlantic Ocean the anomaly of the dynamic depth interval between isobaric surfaces remains nearly constant within certain depth intervals. He has

assumed that surfaces of no motion lie somewhere within these intervals.

In using this method for the Gulf of Mexico data mentioned above, comparisons were made for pairs of stations along each line of stations. The differences between the dynamic depth anomalies from the surface to each standard pressure surface were computed as shown in Table 1, where stations 3 and 4 of Cruise 3 are compared as an example.

Table 1. Computation of differences between the dynamic depth anomalies from the surface to each standard pressure surface for stations 3 and 4, Cruise 3.

Pressure (Decibars)	ΔD_3 (Dynamic meters)	ΔD_4 (Dynamic meters)	$\Delta D_3 - \Delta D_4$ (Dynamic meters)
0	0.000	0.000	0.000
10	.093	.055	.038
20	.142	.106	.042
30	.194	.153	.041
50	.265	.236	.029
75	.333	.318	.015
100	.390	.382	.008
150	.482	.481	.001
200	.552	.560	-.008
250	.614	.629	-.015
300	.672	.691	-.019
400	.777	.804	-.027
500	.871	.903	-.032
600	.955	.993	-.038
700	1.031	1.073	-.042
800	1.100	1.146	-.046
1000	1.219	1.264	-.045
1200	1.323	1.358	-.035

These differences were then plotted against depth (see Figure 2 for example) to ascertain at what depth intervals the anomaly of distance between isobaric surfaces remained most nearly constant. After such intervals were chosen, the assumption was made that a motionless surface

existed at the midpoint of such intervals. Thus in our example (Table 1, Figure 2), the depth of the motionless surface was assumed to be at 900 m., corresponding to a pressure of 900 decibars.

Similar computations were made for all other pairs of stations. The value obtained for each pair of stations was plotted on a base map of the Gulf midway between the pair of stations, and contours drawn. (Figure 3)

4. Hidaka's Method. In 1949, Dr. Koji Hidaka presented a method for determining the depth of the motionless layer (Transactions, American Geophysical Union, Vol. 30, Num. 3) from a consideration of the distribution of salinity. In brief, this method is based on the differential equation governing the distribution of salinity in sea water, that is

$$\frac{\partial S}{\partial t} + u \frac{\partial S}{\partial x} + v \frac{\partial S}{\partial y} + w \frac{\partial S}{\partial z} = k_1 \frac{\partial^2 S}{\partial x^2} + k_2 \frac{\partial^2 S}{\partial y^2} + k_3 \frac{\partial^2 S}{\partial z^2} \quad (1)$$

where S represents salinity, t is time, u , v , and w the x , y and z components of current velocity, and k_1 , k_2 and k_3 the coefficients of diffusion in the x , y and z directions. In a motionless layer, $u = v = w = 0$ and $\frac{\partial S}{\partial t} = 0$ so that (1) becomes

$$k_1 \frac{\partial^2 S}{\partial x^2} + k_2 \frac{\partial^2 S}{\partial y^2} + k_3 \frac{\partial^2 S}{\partial z^2} = 0. \quad (2)$$

In our study in the Gulf of Mexico we have assumed that vertical mixing prevails so that the first two terms of (2) can be neglected. Thus we

need only to consider

$$\frac{\partial^2 S}{\partial z^2} = 0.$$

Using the salinities at standard depths for all stations shown in Figure 1, and the relationship

$$\frac{\partial^2 S}{\partial z^2} = \frac{S_{i-1} + S_{i+1} - 2S_i}{(\Delta h)^2}$$

where S_i is the salinity of the level in question and S_{i-1} and S_{i+1} are the salinities at a distance Δh above and below the level of S_i , values of $\frac{\partial^2 S}{\partial z^2}$ were computed for each standard depth. The point at which $\frac{\partial^2 S}{\partial z^2}$ vanishes was then considered to be the depth of the motionless surface. These depths were plotted at the various station positions and contours drawn as shown in Figure 4.

5. Comparison of Results. A comparison of the results of the methods described above is of interest. It will be noted that with Defant's method, two maxima are obtained, one in the western Gulf and one in the east central Gulf. These maxima also appear in Hidaka's method but both are displaced and are of different magnitudes. The western Gulf maximum in Figure 3 is found to the southeast in Figure 4 with the latter being about 300 m. greater than the former. The east central maximum in Figure 3 is again displaced to the southeast in Figure 4, but in this case the latter is about 600 m. smaller than the former. Both methods show a variation in depth of the motionless layer of from

200 to greater than 1000 m. Moreover, the methods show good agreement in the area of the Yucatan Channel and fair agreement in the Straits of Florida.

In 1936, Dietrich published a chart showing the depth of the motionless surface in the Gulf as inferred from the depth of minimum oxygen content. This method also shows two maxima, one in the western Gulf and one in the east central Gulf, both very close to the positions of the maxima obtained by Defant's method. However, Dietrich's western maximum was at a depth of 400 m. while the east central maximum was at a depth of 600 m. Dietrich's values ranged from 200 to 600 m. They were larger in the Yucatan Channel than the values obtained by using the methods of Defant and Hidaka. They were also larger in the Straits of Florida than the values obtained using Hidaka's method but compared quite favorably in this area with results of the Defant method.

6. Plans for Future Work. As more data become available, it will be possible to study in greater detail the above methods for determining the depth of the motionless layer. More immediately, however, it is planned to check the methods of Defant and Hidaka for mass transport across one or more sections of the Gulf. This, it is hoped, will furnish us with a possible check for one of the methods.

7. Acknowledgements. This work was initiated at the suggestion of Dr. Koji Hidaka who is also the originator of one of the methods used. Mr. Robert O. Reid offered many valuable suggestions in regard to possible future work. Personnel of Project 24 assisted with the computations, typing and drafting.

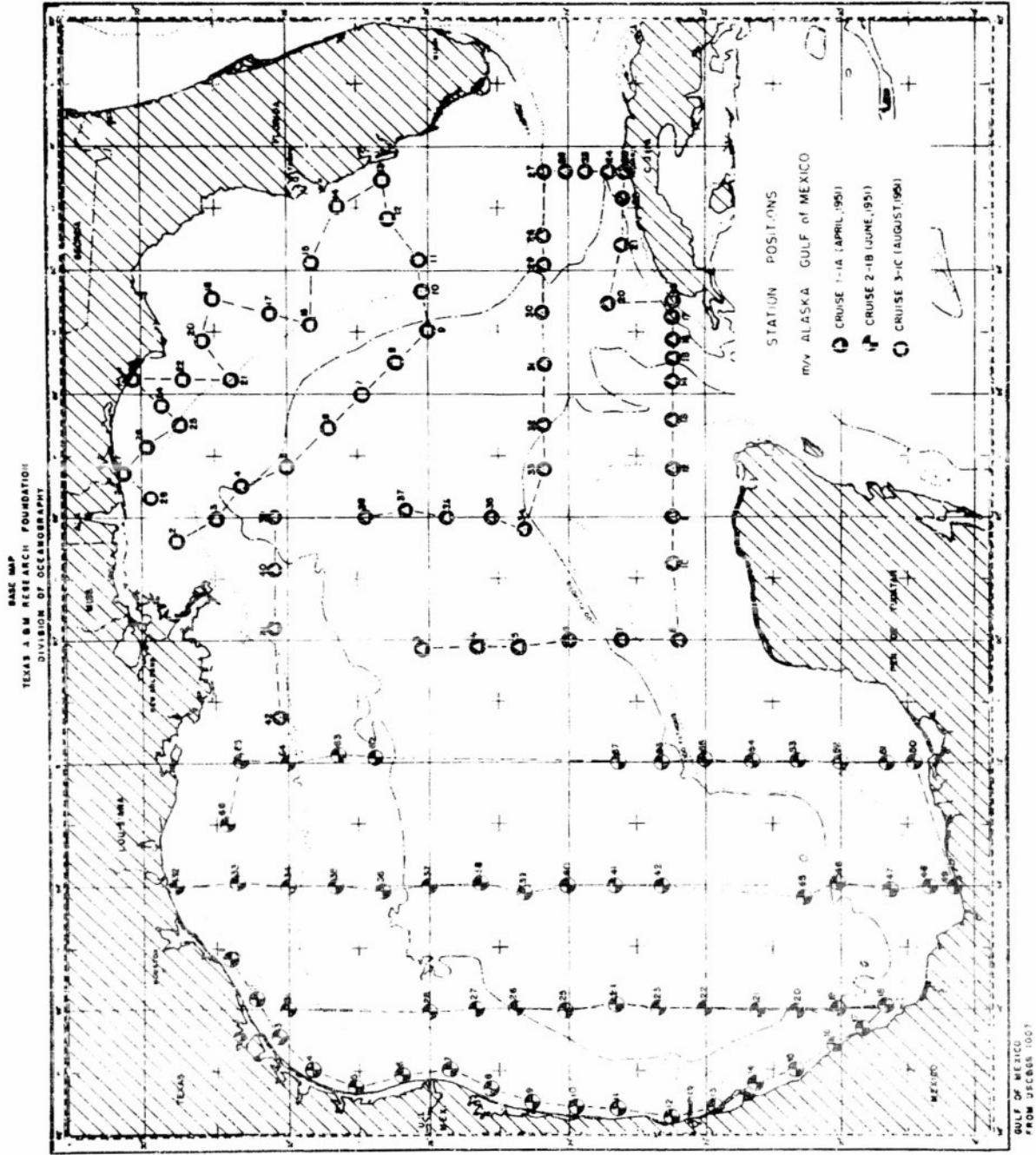


FIGURE 1

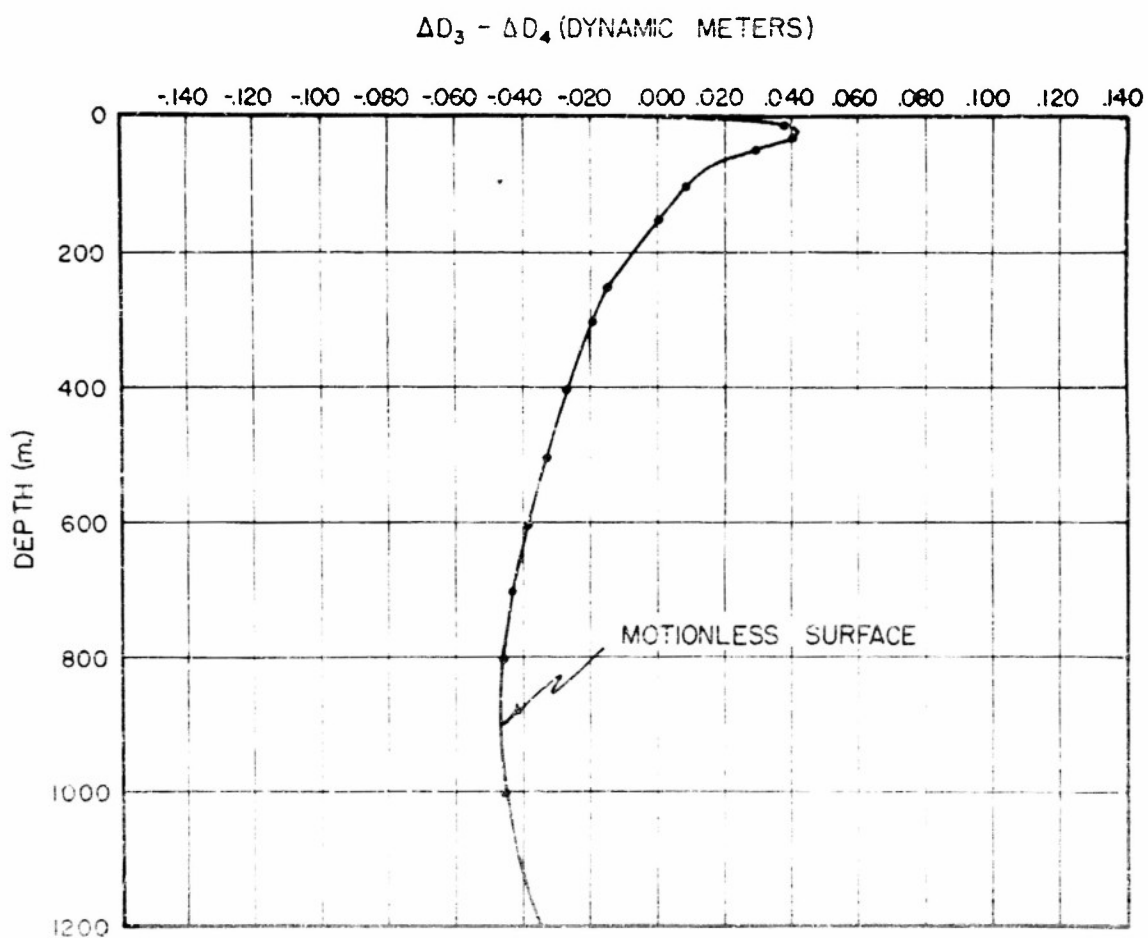
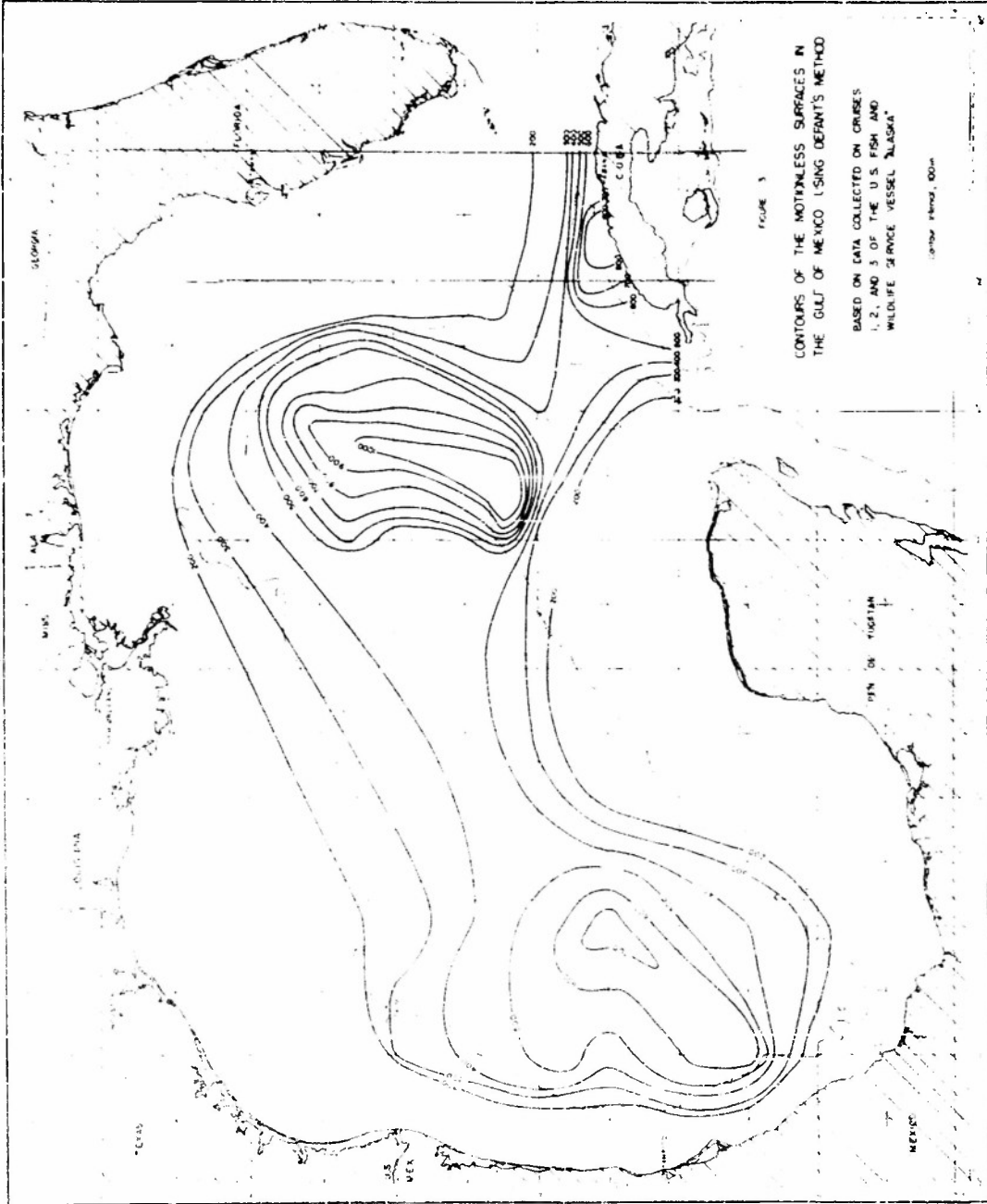


FIGURE 2

DIFFERENCES BETWEEN DYNAMIC DEPTH ANOMALIES FROM THE SURFACE TO EACH STANDARD PRESSURE SURFACE FOR STATIONS 3 AND 4, CRUISE 3.

NET MAP
TEXAS A & M UNIVERSITY FOUNDATION
DIVISION OF OCEANOGRAPHY



GULF OF MEXICO
FRENCH 155085-1107

BASE MAP
TEXAS A & M RESEARCH FOUNDATION
DIVISION OF OCEANOGRAPHY

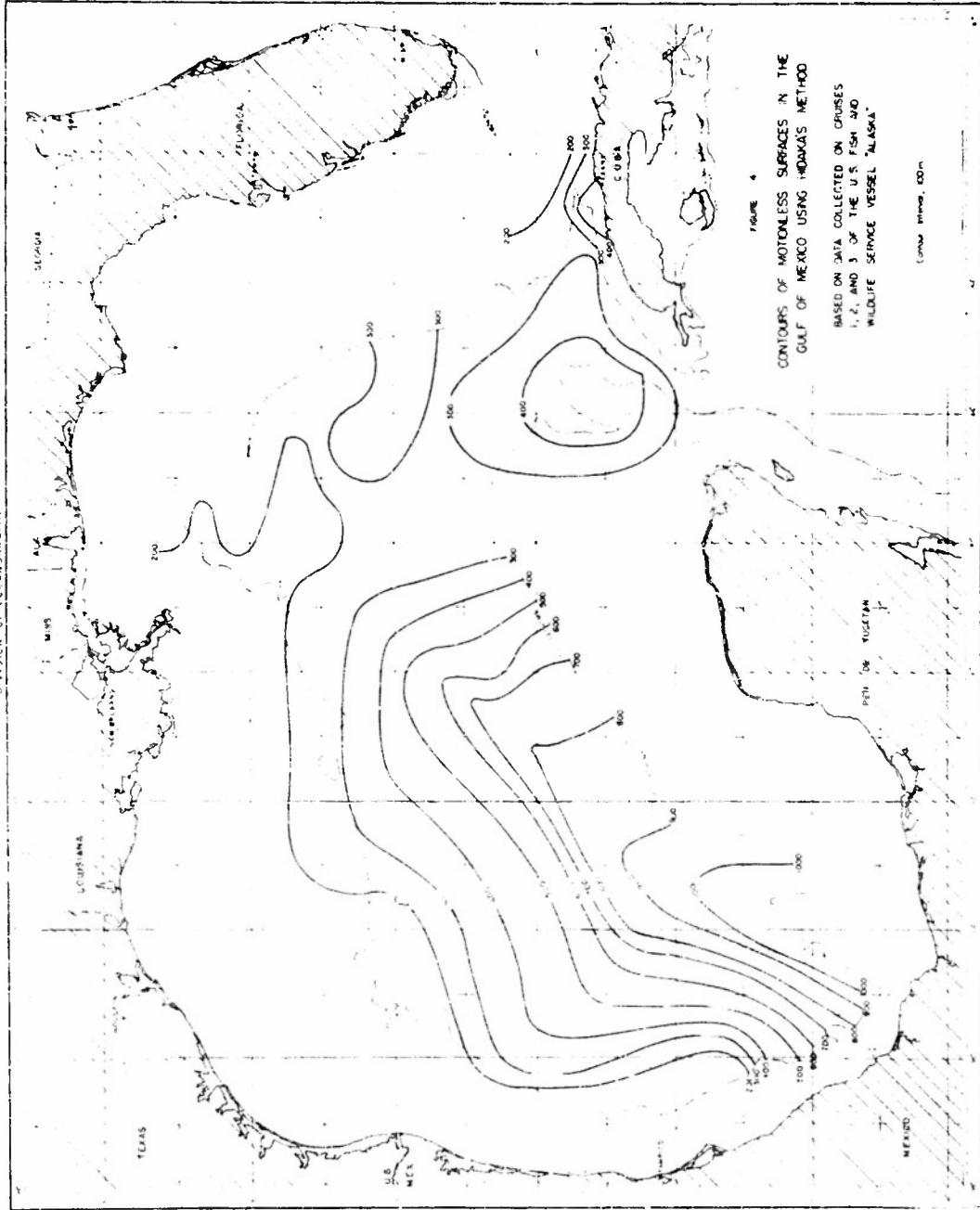


FIGURE 4
CONTOURS OF MOTILELESS SURFACES IN THE
GULF OF MEXICO USING HOWARD'S METHOD

BASED ON DATA COLLECTED ON CRUISES
1, 2, AND 3 OF THE U.S. FISH AND
WILDLIFE SERVICE VESSEL "ALASKA"

Contour Interval, 100m

GULF OF MEXICO
FROM SC55B 007

DISTRIBUTION LIST

<u>No.</u> <u>Copies</u>	<u>Addressee</u>	<u>No.</u> <u>Copies</u>	<u>Addressee</u>
6	Chief of Naval Research Navy Department Washington 25, D. C. Attn: Code 416 (2) " Code 446 (3) " Code 466 (1)	1	Commanding Officer U.S. Navy Underwater Sound Laboratory New London, Connecticut
1	ONR Resident Representative University of Texas Main Building, Room 2506 Austin 12, Texas	6	Director, Naval Research Laboratory Attn: Technical Information Officer Washington 25, D. C.
1	Office of Naval Research Branch Office 1000 Geary Street San Francisco 9, California	1	Chief, Bureau of Yards & Docks Navy Department Washington 25, D. C.
1	Office of Naval Research Branch Office Tenth Floor 86 E. Randolph St. Chicago 1, Illinois	1	Commander Naval Ordnance Laboratory White Oak Silver Spring 19, Maryland
1	Office of Naval Research Branch Office 346 Broadway New York 13, New York	2	Asst. Naval Attache for Research American Embassy Navy 100 Fleet Post Office, New York
1	Office of Naval Research Branch Office 1030 E. Green Street Pasadena 1, California	3	British Joint Services Mission Main Navy Building Washington 25, D. C.
8	U. S. Navy Hydrographic Office Washington 25, D. C. Attn: Division of Oceanography	2	Officer-In-Charge Office of Naval Research London Branch Office Navy # 100 Fleet Post Office, New York, N. Y.
5	Chief, Bureau of Ships Navy Department Washington 25, D. C. Attn: Code 847 (2) " Code 816 (2) " Code 845 (1)	1	Commanding General Research and Development Div. Department of the Army Washington 25, D. C.
4	Director, U.S. Navy Electronics Laboratory San Diego 52, California Attn: Codes 550, 551, 552, 610	1	U. S. Army Beach Erosion Board 5201 Little Falls Road, NW Washington 16, D. C.

DISTRIBUTION LIST CONT'D.

<u>No.</u> <u>Copies</u>	<u>Addressee</u>	<u>No.</u> <u>Copies</u>	<u>Addressee</u>
1	Department of Aerology U. S. Naval Post Graduate School Monterey, California	1	Office of Technical Services Department of Commerce Washington 25, D. C.
1	Project Arowa U. S. Naval Air Station Building R-4E Norfolk, Virginia	1	U. S. Weather Bureau U. S. Department of Commerce Washington 25, D. C. Attn: Scientific Services
1	Research and Development Board National Military Establishment Washington 25, D. C. Attn: Committee on Geophysics and Geography	1	Commanding Officer Cambridge Field Station 230 Albany Street Cambridge 39, Massachusetts Attn: CRHSL
1	Assistant Secretary for Defense for Research and Development Attn: Committee on Geophysics and Geography Pentagon Building Washington 25, D. C.	1	Commandant (QAO) U. S. Coast Guard Washington 25, D. C.
5	Armed Services Technical Information Center Documents Service Center Knott Building Dayton 2, Ohio	1	Director U. S. Coast and Geodetic Survey Department of Commerce Washington 25, D. C.
1	Commanding General Research and Development Div. Department of the Air Force Washington 25, D. C.	1	U. S. Fish & Wildlife Service P. O. Box 3830 Honolulu, T. H.
1	Chief of Naval Operations Navy Department Washington 25, D. C. Attn: Op-533 D	1	U. S. Fish & Wildlife Service Woods Hole, Massachusetts
1	The Chief, Armed Forces Special Weapons Project P. O. Box 2610 Washington 25, D. C.	1	U. S. Fish & Wildlife Service South Atlantic Offshore Fishery Investigations c/o Georgia Game & Fish Commission P. O. Box 312 Brunswick, Georgia
1	Office of the Quartermaster General Military Planning Division Research and Development Branch Washington 25, D. C.	3	U. S. Fish & Wildlife Service Department of the Interior Washington 25, D. C. Attn: Dr. L. A. Walford
1		2	U. S. Fish & Wildlife Service Fort Crockett Galveston, Texas

DISTRIBUTION LIST CONT'D.

<u>No.</u> <u>Copies</u>	<u>Addressee</u>	<u>No.</u> <u>Copies</u>	<u>Addressee</u>
1	U. S. Fish & Wildlife Service 450 B. Jordan Hall Stanford University, California	2	Director Woods Hole Oceanographic Institute Woods Hole, Massachusetts
1	Director Narragansett Marine Laboratory Kingston, Rhode Island	1	Director Chesapeake Bay Institute Box 426A, RFD #2 Annapolis, Maryland
1	Director, Hawaii Marine Laboratory University of Hawaii Honolulu, T. H.	1	Head, Department of Oceanography University of Washington Seattle, Washington
1	Director, Marine Laboratory University of Miami Coral Gables, Florida	1	Bingham Oceanographic Foundation Yale University New Haven, Connecticut
1	Director Lamont Geological Observatory Torrey Cliff Palisades, New York	1	Allen Hancock Foundation University of Southern California Los Angeles 7, California
1	Department of Conservation Cornell University Ithaca, New York Attn: Dr. J. Ayers	1	Head Department of Oceanography Brown University Providence, Rhode Island
1	Department of Zoology Rutgers University New Brunswick, New Jersey Attn: Dr. H. H. Haskins	1	Dr. Willard J. Pierson New York University New York, New York
2	Scripps Institution of Oceanography La Jolla, California Attn: Director (1) " Library (1)	1	Secretary, Gulf States Marine Fisheries Commission Audubon Building 931 Canal Street New Orleans 16, Louisiana
1	The Oceanographic Institute Florida State University Tallahassee, Florida	1	Texas Game and Fish Commission Rockport, Texas
1	Department of Engineering University of California Berkeley, California		

DISTRIBUTION LIST CONT'D.

<u>No.</u> <u>Copies</u>	<u>Addressee</u>	<u>No.</u> <u>Copies</u>	<u>Addressee</u>
1	Secretary Atlantic States Marine Fisheries Commission 22 West 1st Street Mount Vernon, New York Attn: Wayne D. Heydecker	1	Director, University of Florida Marine Biological Station Gainsville, Florida
1	California Academy of Sciences Golden Gate Park San Francisco, California Attn: Dr. R. C. Miller	1	Director, Alabama Marine Laboratory Bayou La Batre, Alabama
1	Director Institute of Marine Science Port Aransas, Texas	1	Southern Regional Education Board Marine Sciences 330 West Peachtree Street, NW Atlanta, Georgia
1	Director Gulf Coast Research Laboratory Ocean Springs, Mississippi	1	Director Louisiana State University Marine Laboratory Baton Rouge, Louisiana
1	American Museum of Natural History Central Park West at 74th Street New York 24, New York	1	Director, Institute of Fisheries Research University of North Carolina Morehead City, North Carolina
1	Head, Department of Biology Texas Christian University Ft. Worth. 9, Texas	1	Director Duke University Marine Laboratory Beaufort, North Carolina
1	Head, Dept. of Meteorology and Oceanography New York University New York, New York	1	Institute of Engineering Research 244 Hesse Hall Berkeley 4, California Attn: Prof. J. W. Johnson
1	Bear's Bluff Laboratory Wadmalaw Island, South Carolina Attn: Dr. Robert Lunz	1	Chief, Air Weather Service Department of the Air Force Washington, D. C.
1	Department of Biology University of Florida Gainsville, Florida Attn: Mr. E. Lowe Pierce	1	U. S. Waterways Experiment Station Vicksburg, Mississippi
1	Director, Virginia Fisheries Laboratory College of William and Mary Gloucester Point, Virginia	1	Library Southwest Research Institute 8500 Culebra Road San Antonio 6, Texas