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Volume 2: Temporal Distribution of Bathythermograph Profiles

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PREFACE

The oceanographic databases described by this atlas series greatly expands on the *World Ocean Database 1998* (WOD98) product. We have expanded these earlier databases to include data from new instrument types such as profiling floats and new variables such as pCO_2 and TCO_2. Previous oceanographic databases including the NODC/WDC profile archives, and products derived from these databases, have proven to be of great utility to the international oceanographic, climate research, and operational environmental forecasting communities. In particular, the objectively analyzed fields of temperature and salinity derived from these databases have been used in a variety of ways. These include use as boundary and/or initial conditions in numerical ocean circulation models, for verification of numerical simulations of the ocean, as a form of "sea truth" for satellite measurements such as altimetric observations of sea surface height, and for planning oceanographic expeditions. Increasingly nutrient fields are being used to initialize and/or verify biogeochemical models of the world ocean. The databases, and products based on these databases, are critical for support of international assessment programs such as the Intergovernmental Program on Climate Change (IPCC) of the United Nations.

It is well known that the amount of carbon dioxide in the earth's atmosphere will most likely double during the next century compared to CO_2 levels that occurred at the beginning of the Industrial Revolution. Regardless of one's scientific and/or political view of a possible "enhanced greenhouse warming" due to the increase of carbon dioxide, it is necessary that the international scientific community have access to the most complete historical oceanographic databases possible in order to study this problem, as well as other scientific and environmental problems.

The production of oceanographic databases is a major undertaking. Such work benefits from the input of many individuals and organizations. We have tried to structure the data sets in such a way as to encourage feedback from experts around the world who have knowledge that can improve the data and metadata contents of the database. It is only with such feedback that high quality global ocean databases can be prepared. Just as with scientific theories and numerical models of the ocean and atmosphere, the development of global ocean databases is not carried out in one giant step, but proceeds in an incremental fashion.

In the acknowledgment section of this publication we have expressed our view that creation of global ocean databases is only possible through the cooperation of scientists, data managers, and scientific administrators throughout the international community. I thank my colleagues at the Ocean Climate Laboratory of NODC for their dedication to the project leading to publication of this atlas series. Their commitment has made this database possible. It is my belief that the development and management of national and international oceanographic data archives is best performed by scientists who are actively working with the data.

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March 2002

Acknowledgments

This work was made possible by a grant from the NOAA Climate and Global Change Program which enabled the establishment of a research group, the Ocean Climate Laboratory (OCL), at the National Oceanographic Data Center. The purpose of the OCL is to prepare research quality oceanographic databases, as well as to compute objective analyses of, and diagnostic studies based on, these databases.

The data made available as part of this atlas include a part of the oceanographic data archives maintained by NODC/WDC as well as data acquired as a result of the IODE/IOC "Global Oceanographic Data Archaeology and Rescue" (GODAR) project. At NODC/WDC, "data archaeology and rescue" projects are supported with funding from the NOAA Environmental Science Data and Information Management (ESDIM) Program and NOAA Climate and Global Change Program. The majority of funding for these efforts is now provided by the ESDIM program. Support for this work from joint NASA/NOAA and DOE/NOAA Global Change data management programs is appreciated. Support for some of the regional IOC/GODAR meetings was provided by the MAST program of the European Union.

We acknowledge the scientists, technicians, and programmers who have submitted data to national and regional data centers as well as the managers and staff at the various data centers. Our database allows for the storage of metadata including information about Principal Investigators to recognize their efforts.

The OCL expresses thanks to those who provided comments and helped develop an improved *World Ocean Database 2001* (WOD01) product. In particular, Dr. Steve Worley of NCAR, and Steve Hankin of PMEL for testing the CD-ROMs prior to distribution. Roy Lowry (BODC) and Tom Whitworth (TAMU) for suggestions. Any errors in WOD01 are the responsibility of the Ocean Climate Laboratory.

Ervin Godfrey Trammell and Charlotte Sazama of the NODC International Data Exchange Team helped locate data in the WDC archives for digitization. We thank Mike Chepurin, Igor Minin, Dan Smolyar, Alexandra Grodsky, and Carla Forgy of the OCL for their work in data digitization and their assistance in quality control of the data and metadata in WOD01. Renee Tatusko identified many missing metadata. The OCL acknowledges the help received over the last several years from colleagues in other NODC divisions. Francis Mitchell helped with all the code lists and accessions, Melanie Hamilton supplied GTSPP data.

Declassification of naval oceanographic data by various navies is acknowledged. The Intergovernmental Oceanographic Commission has requested such declassification efforts in recent years.

World Ocean Database 2001, Volume 2: Temporal Distribution of Bathythermograph Profiles

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ABSTRACT

This atlas describes a collection of scientifically quality controlled ocean Mechanical Bathythermograph (MBT) and Expendable Bathythermograph (XBT) profiles. Data distributions for individual years of all MBT and XBT profiles in the database are presented to provide information on the state of ocean MBT and XBT profile observations.

Chapter 1: Temporal Distribution of Mechanical Bathythermograph Profiles

1. INTRODUCTION

The Mechanical Bathythermograph (MBT) is an instrument developed during the late-1930's (Spilhaus, 1938) that can be dropped from either a stationary or moving ship to produce an upper ocean temperature profile. This instrument was a substantial improvement of an instrument known as the "oceanograph" which was designed by Dr. Carl Rossby and Dr. Karl Lange (Rossby and Montgomery, 1934) for the purpose of studying the upper ocean thermal structure. The introduction of the MBT into usage allowed ships to make synoptic surveys of oceanographic regions and for discovery of fine structure of the ocean's thermal structure. Spilhaus (1941) used the instrument to identify "fine" structure (in the horizontal) from temperature profiles near the edge of the Gulf Stream. Pressure is determined from a pressure sensitive tube known as a Bourdon tube. A temperature sensitive element in the nose of the MBT enables the instrument to trace temperature as a function of depth.

Different versions of the MBT have different maximum depth ranges with 295 m being the deepest depth measured from any U.S. version. Earlier versions of the instrument were limited to making measurements in the upper 140 m of the water column. A review of the development of the MBT is given by Spilhaus (1987). Another more comprehensive review is provided by Couper and LaFond (1970).

The Digital Bathythermograph (DBT) instrument is a version of the MBT that reports data electronically rather than mechanically and may reach depths deeper than 295 m. DBT profiles are included in the MBT files.

2. MBT ACCURACY

The accuracy of the MBT has been the subject of several studies. Leipper and Burt (1948) report the results of comparisons between MBT temperature measurements and near simultaneous reversing thermometer measurements which were made by D. Pritchard of the U.S. Navy Electronics Laboratory in Lake Meade. By comparing the temperature traces on the up and down casts of the MBT it was inferred that there was " an almost complete absence of internal waves of large amplitude and short period, hysteresis of the instruments, or rapid temperature changes due to advection". These results are reproduced in Table 1 given below. Clearly there is good agreement between the reversing thermometer measurements (which typically had an accuracy of 0.02°C at this period of time and the MBT measurements. However, there is a problem with interpreting the results from Table 1 because it is not clearly stated in the table or the text of the technical report of Leipper and Burt, what temperature units were used. Throughout their report, Leipper and Burt use the Fahrenheit scale. If this scale applies to the results in Table 1, then the agreement is impressive. If the results are in degrees centigrade, the agreement is less impressive but the data are still useful for many scientific purposes. Other studies attribute an accuracy of about 0.5°F to the MBT instrument (This figure is comparable to the accuracy of Expendable Bathythermograph (XBT) probes for which the thermistor sensing element is not calibrated (Tabata, 1978)). Although both MBT and XBT probes are an order of magnitude less precise than reversing thermometers, the *standard error of the mean* of any estimate based on these temperature measurements decreases with the increase in number of data used. This applies to random errors. Hence, historical bathythermograph measurements provide valuable information when estimating mean features for by averaging over many measurements in space and/or time.

In many countries and institutions the use of the MBT has been replaced by the XBT but in other countries and institutes MBT measurements continue to be made and transferred to oceanographic data centers.

3. MBT PROFILE DISTRIBUTIONS

Figure 1 shows the number of MBT profiles contained in WOD01 for the World Ocean as a function of year. Figures 2 and 3 show the time series for the northern and southern hemispheres respectively. There are a total of 2,376,206 MBT profiles for the entire World Ocean with 264,648 profiles (11.1%) measured in the southern hemisphere and 2,111,558 profiles (88.9%) measured in the northern hemisphere. Table 1 provides the exact number of MBT profiles included in WOD01 as a function of year. Substantial numbers of MBT profiles were made by the U.S. Navy during World War II. All the WWII Pacific and Indian Ocean MBT profiles were digitized during the past several years as part of the NODC Data Archaeology and Rescue (NODAR) project with support from the NOAA CGC (Climate and Global Change) program and the NOAA ESDIM (Environmental Sciences and Information Management program). These data have been stored at the Scripps Institute of Oceanography. A more complete description of the data in this archive can be found in the report by Levitus *et al.* (1998). The geographic distribution of MBT profiles for individual years for 1941-1994 are shown in Figures A1-A54. Most profiles have been made in the northern hemisphere, but the southern hemisphere coverage has been increased due to international data archaeology and rescue efforts and the World Ocean Database project (Levitus *et al.* 1994, 2002).

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Table 1. Comparison of observations taken with Mechanical Bathythermographs and reversing thermometers reproduced from Leipper and Burt (1948).

TABLE I

OBSERVATIONS TAKEN WITH BATHYTHERMOGRAPHS AND REVERSING THERMOMETERS

BT	No. of stations	No. of thermometer observations	Standard Deviation of Temperature Differences*
# 1784A (Shallow)	9	20	0.15
# 1258A (Deep)	10	41	0.19
# 514A (Deep)	12	36	0.10

*We reproduce this table as it appeared in the work by Leipper and Burt (1948). Unfortunately, they did not specify whether the units of temperature were reported in degrees centigrade or Fahrenheit . However, all other citations of temperature in their report were given in units of degrees Fahrenheit. Even if these results are in units of degrees centigrade, the agreement is still good. For example, individual XBT probes are accurate to a few tenths of a degree Centigrade.

Table 2 National contributions of Mechanical Bathythermograph (MBT) profiles sorted by percent contribution of each country

NODC Country Code	Country Name	MBT Count	% of Total
31	UNITED STATES	1100903	46.31
90	RUSSIA	432966	18.21
49	JAPAN	335247	14.10
18	CANADA	195947	8.24
74	UNITED KINGDOM	118644	4.99
32	UNITED STATES	46660	1.96
6	GERMANY, FEDERAL REPUBLIC OF	25005	1.05
33	UNITED STATES	23103	0.97
9	AUSTRALIA	18474	0.78
99	UNKNOWN	16636	0.70
35	FRANCE	13538	0.57
8	ARGENTINA	12303	0.52
64	NETHERLANDS	8088	0.34
48	ITALY	6268	0.26
65	PERU	5212	0.22
20	CHILE	4161	0.18
68	PORTUGAL	2628	0.11
61	NEW ZEALAND	2435	0.10
RC	CONGO	1234	0.05
11	BELGIUM	1218	0.05
58	NORWAY	913	0.04
28	ECUADOR	885	0.04
24	KOREA, REPUBLIC OF	847	0.04
22	COLOMBIA	747	0.03
93	VENEZUELA	673	0.03
41	INDIA	540	0.02
55	MALAGASY REPUBLIC	405	0.02
36	GREECE	327	0.01
SE	SENEGAL	245	0.01
29	SPAIN	195	0.01
SL	SIERRA LEONE	187	0.01
IC	IVORY COAST	100	0.00
MO	MONACO	97	0.00
NI	NIGERIA	89	0.00
14	BRAZIL	82	0.00
86	THAILAND	77	0.00
91	SOUTH AFRICA	20	0.00
GH	GHANA	12	0.00

The United States, Russia, and Japan have multiple country codes. This is because the NODC Institution Code is limited to two digits and these countries each have more than 99 institutions that can potentially transfer data to NODC/WDC.

Table 3 The number of all MBT profiles in WOD01 as a function of year for the World Ocean.

Total Number of Profiles = 2,376,206

YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE
1941	10154	1956	50666	1971	40974	1986	44478
1942	7014	1957	60580	1972	43558	1987	40704
1943	17767	1958	70159	1973	34112	19882	34877
1944	36902	1959	65526	1974	35133	1989	21223
1945	41127	1960	72367	1975	27446	1990	18703
1946	23823	1961	77009	1976	33564	1991	8348
1947	28826	1962	85559	1977	34214	1992	3832
1948	30364	1963	91652	1978	35750	1993	3676
1949	36058	1964	89173	1979	39695	1994	81
1950	50364	1965	97277	1980	31128	1995	10
1951	50296	1966	106984	1981	26671	1996	0
1952	61351	1967	94321	1982	23704	1997	0
1953	59352	1968	75460	1983	25224	1998	0
1954	52966	1969	60796	1984	39829	1999	5
1955	45560	1970	44918	1984	35616		

Table 4 The number of all MBT profiles in WOD01 as a function of year for the southern hemisphere.

Total Number of Profiles = 264,648

YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE
1941	10	1956	4306	1971	6362	1986	6007
1942	1384	1957	8468	1972	6522	1987	6409
1943	2568	1958	10700	1973	6169	1988	3654
1944	3389	1959	9195	1974	4839	1989	2661
1945	1007	1960	9994	1975	2487	1990	1353
1946	914	1961	6945	1976	5104	1991	434
1947	2169	1962	9447	1977	6985	1992	116
1948	143	1963	11417	1978	5986	1993	172
1949	550	1964	9935	1979	6857		
1950	287	1965	10383	1980	5916		
1951	469	1966	10695	1981	4665		
1952	2764	1967	13940	1982	4172		
1953	886	1968	10810	1983	4911		
1954	1057	1969	5901	1984	8200		
1955	2978	1970	5956	1984	6000		

Table 5 The number of all MBT profiles in WOD01 as a function of year for the northern hemisphere.

Total Number of Profiles = 2,111,558

YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE
1941	10144	1956	45760	1971	34612	1986	38471
1942	5630	1957	52112	1972	37036	1987	34295
1943	15199	1958	59459	1973	27943	1988	31223
1944	33513	1959	56331	1974	30294	1989	18562
1945	40120	1960	62373	1975	24959	1990	17350
1946	22909	1961	70064	1976	28460	1991	7914
1947	26657	1962	76112	1977	27229	1992	3716
1948	30191	1963	80145	1978	29764	1993	3504
1949	35508	1964	79238	1979	32838	1994	81
1950	50077	1965	86894	1980	25212	1995	10
1951	49827	1966	96289	1981	22006	1996	0
1952	58587	1967	80381	1982	19532	1997	0
1953	58466	1968	64650	1983	20313	1998	0
1954	51909	1969	54895	1984	31629	1999	5
1955	42582	1970	38962	1984	29616		

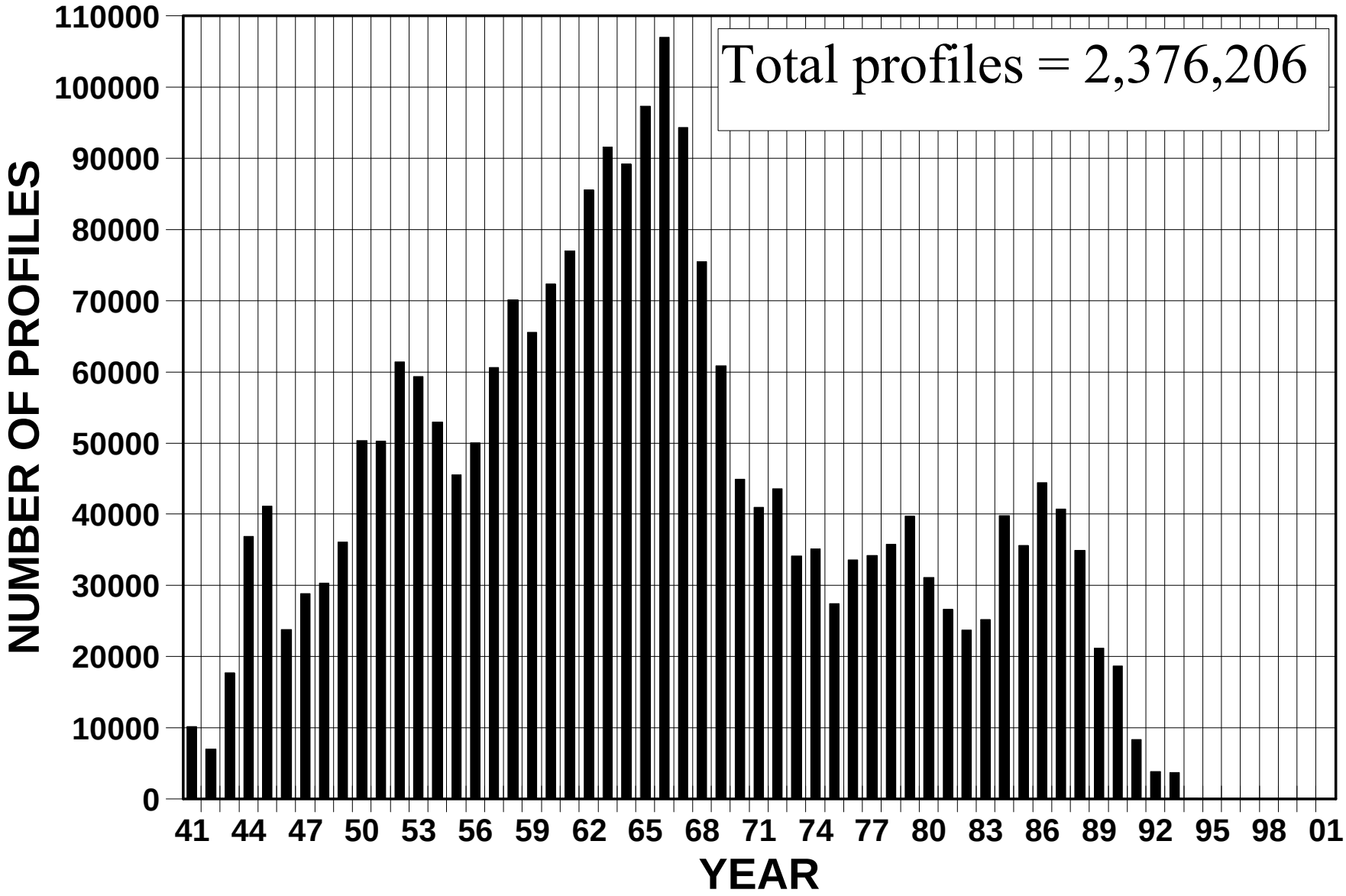

Fig. 1 Time series of MBT profiles in WOD01 for the world ocean as a function of year.

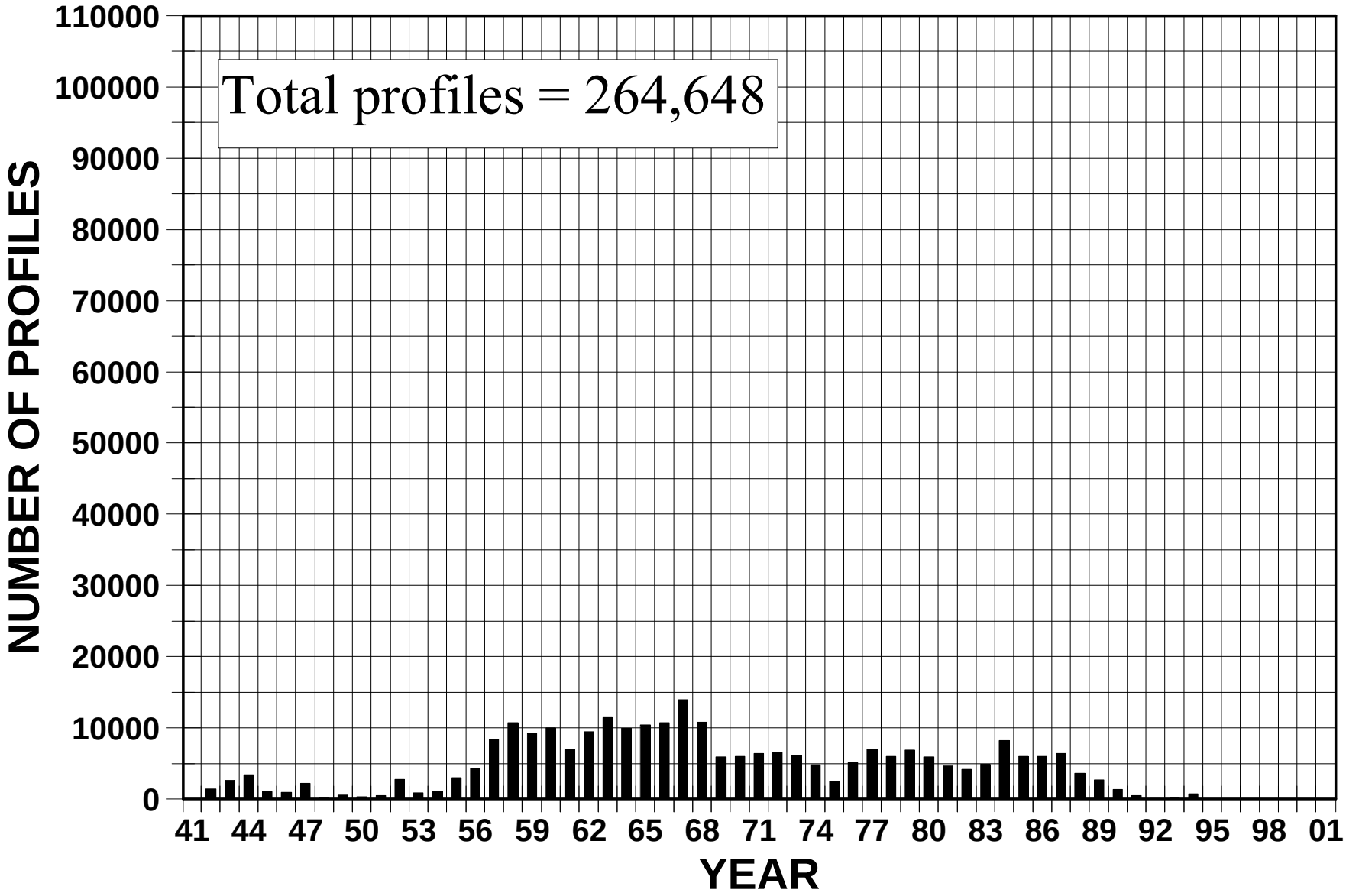

Fig. 2 Time series of MBT profiles in WOD01 for the southern hemisphere as a function of year.

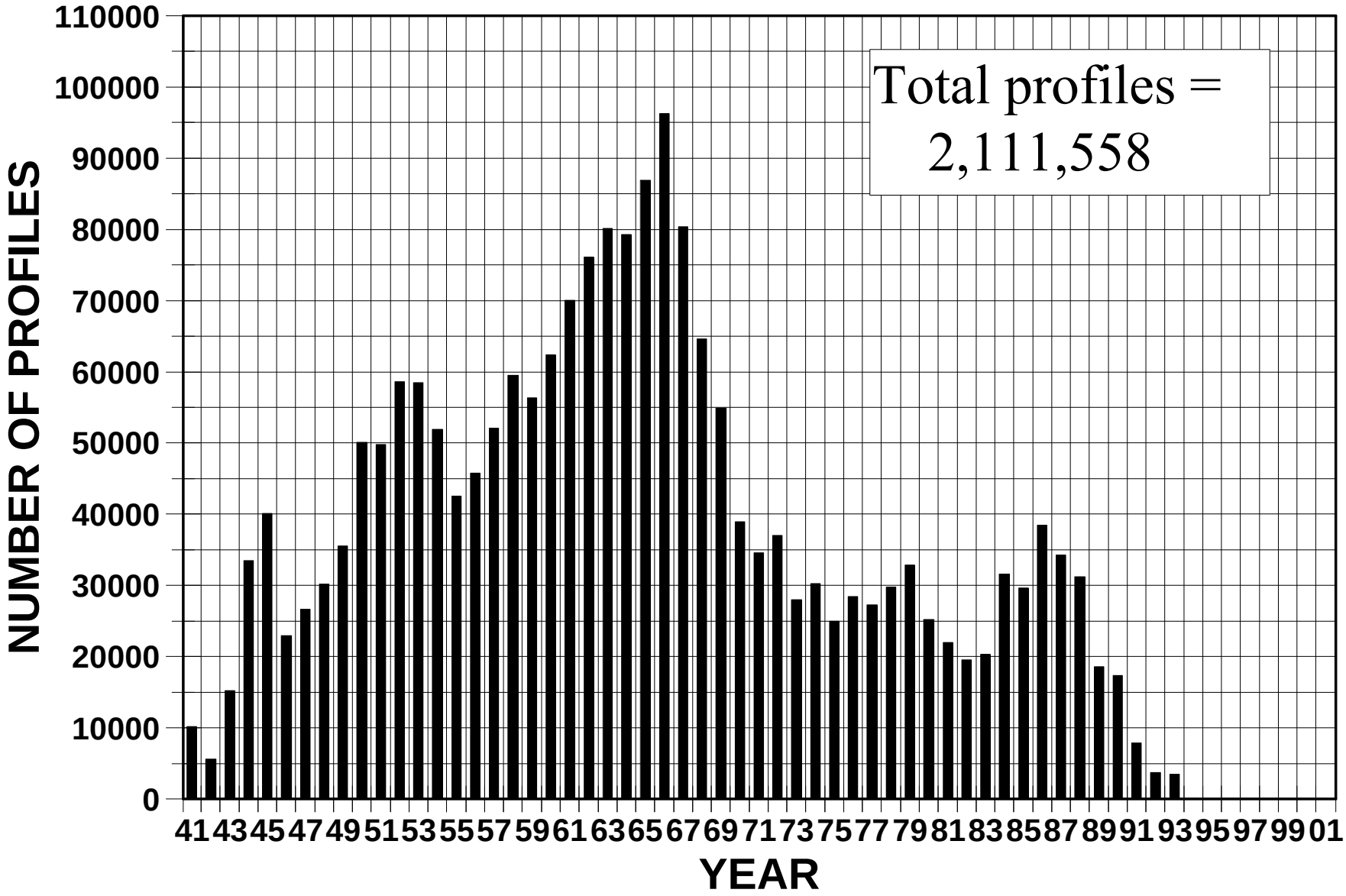

Fig. 3 Time series of MBT profiles in WOD01 for the northern hemisphere as a function of year.

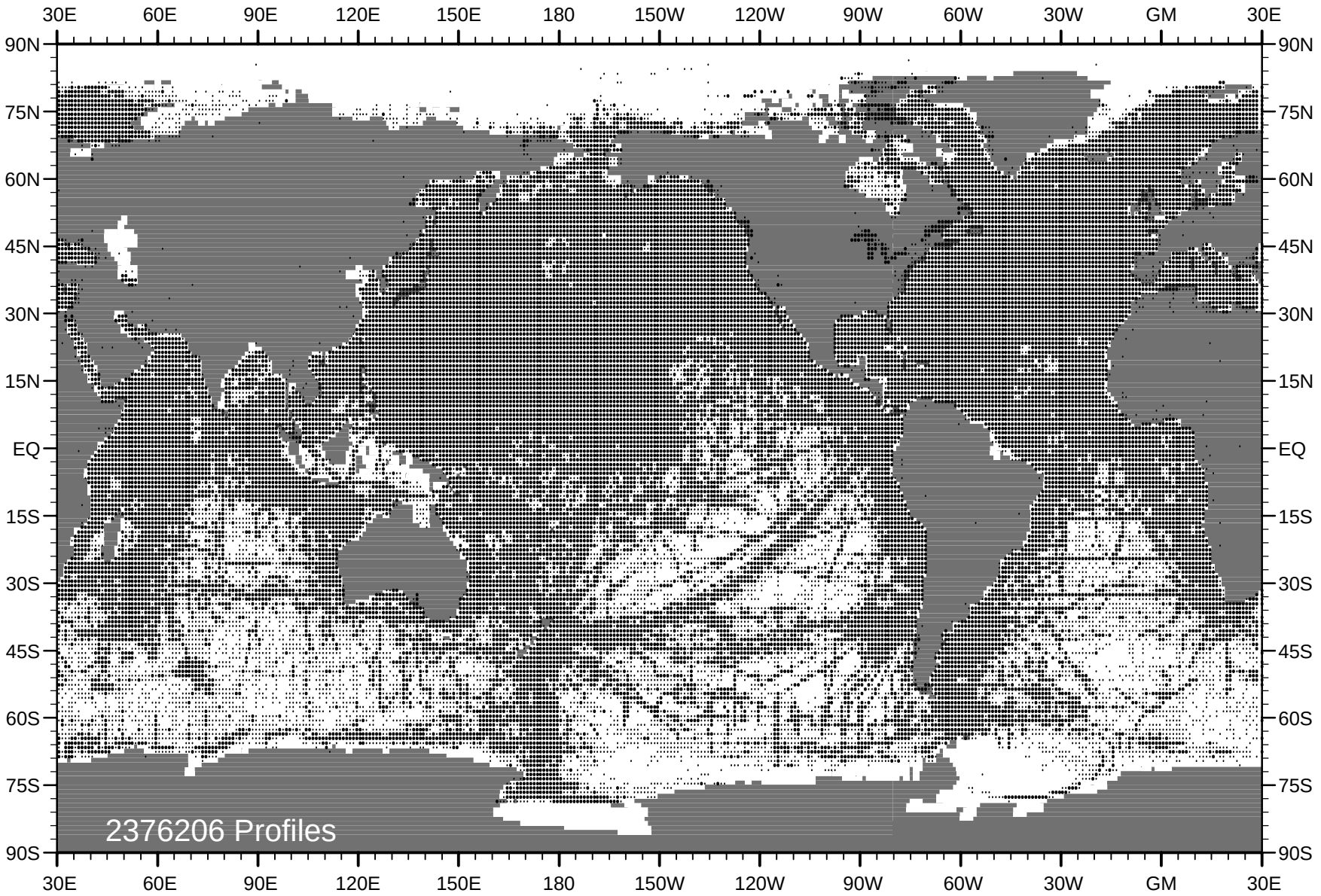

Fig. 4 Distribution of all profiles in the MBT files of WOD01.
Dots show location of 1-degree squares containing any data.

5. APPENDIX A: DISTRIBUTIONS FOR INDIVIDUAL YEARS OF ALL MBT PROFILES IN WOD01

This appendix contains yearly data distributions of all MBT profile data contained in WOD01. These maps provide some history of the observational progress of the field of oceanography. They also serve as indicators of whether or not a particular data set from a scientist or institution is part of the NODC/WDC archive. The exchange of information provided by the publication of such maps has provided us with valuable information about deficiencies in the database. The locations of all WOD01 MBT profiles are plotted including profiles that may be erroneously located over land. However, WOD01 contains some profiles from various lakes so care should be exercised in the use of these profiles and the determination as to whether they represent errors in locations.

For all figures in Appendix A, a small dot indicates a one-degree square containing from one to four profiles and a large dot indicates five or more profiles.

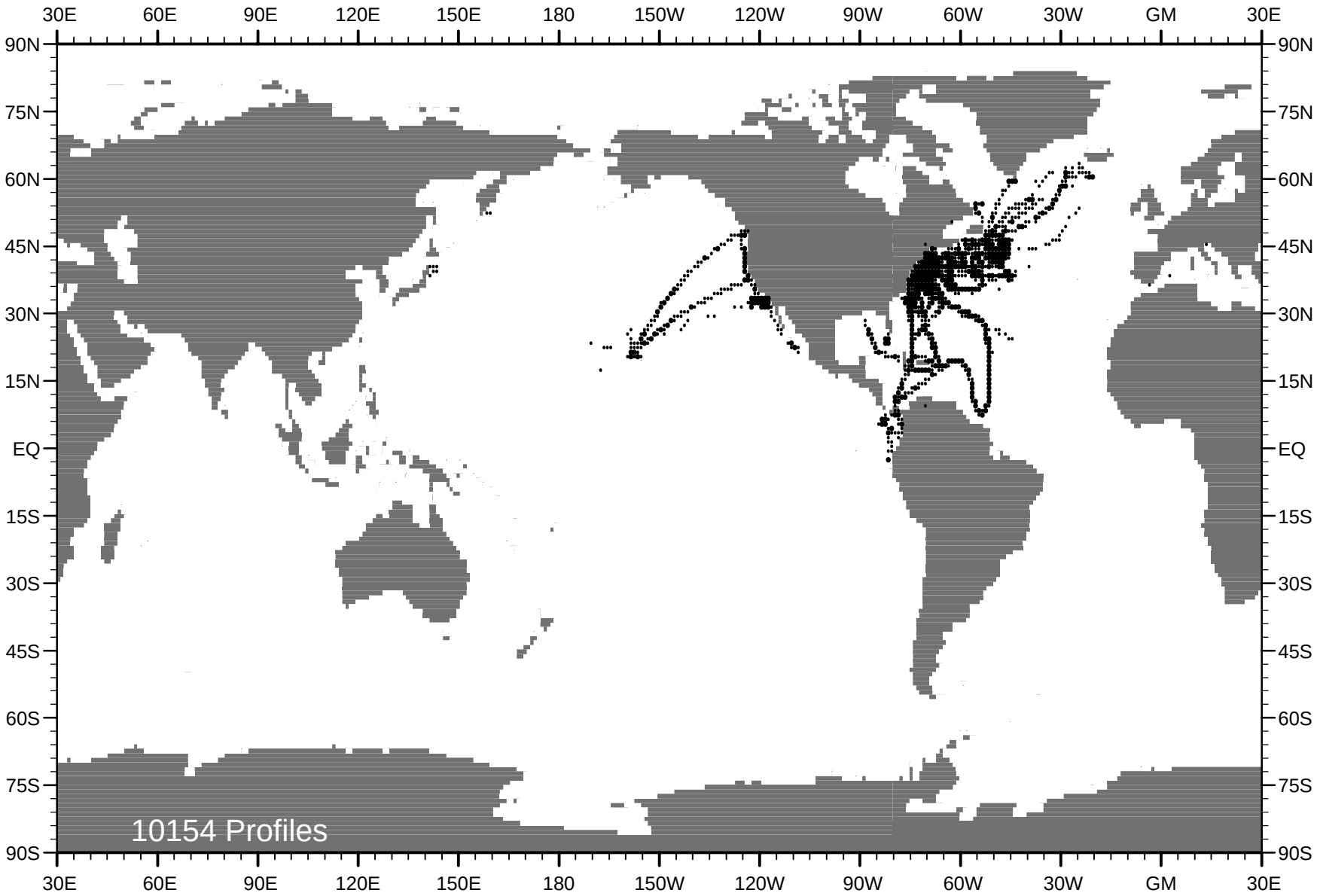

Fig. A1 WOD01 MBT profile distribution for year 1941 .

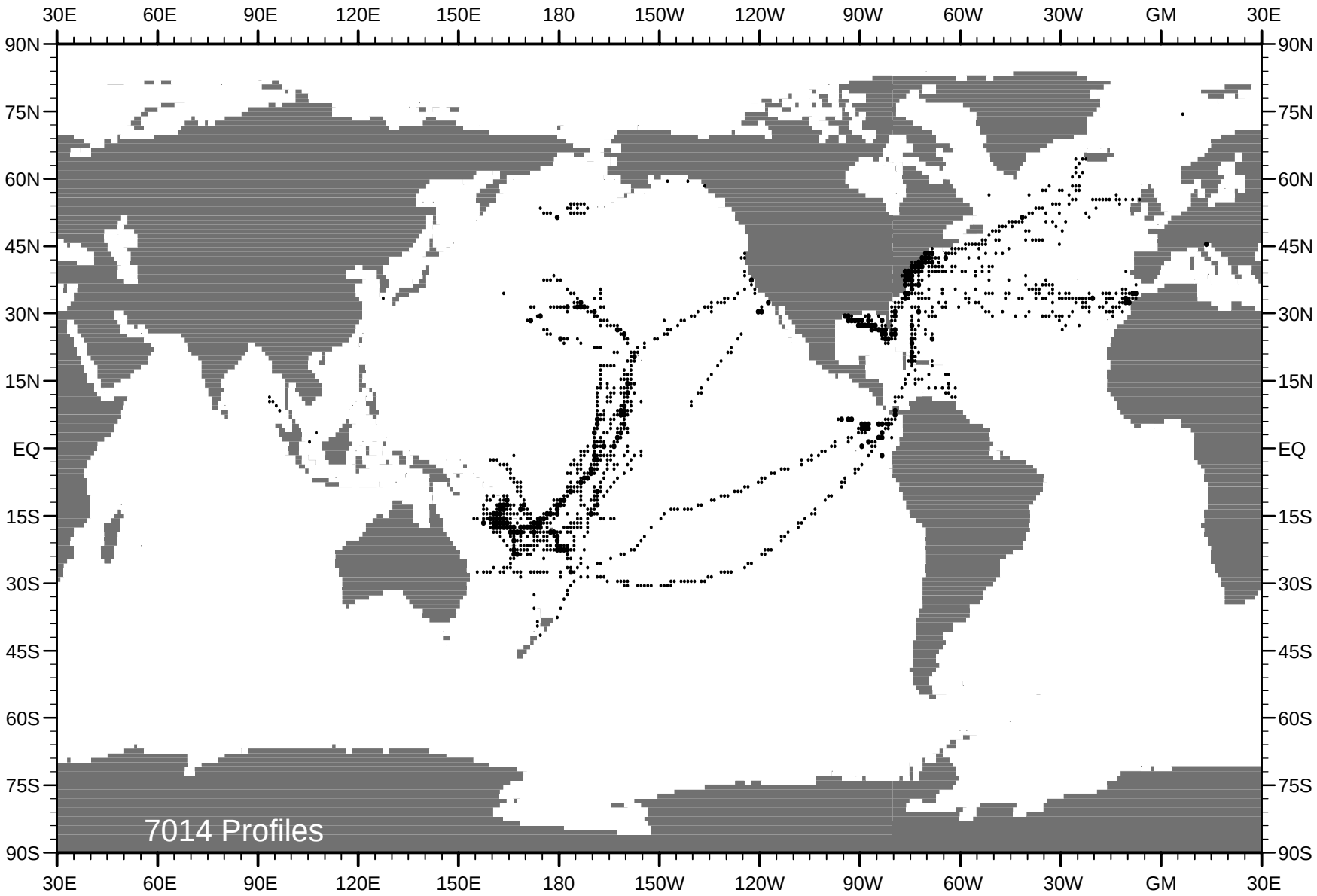

Fig. A2 WOD01 MBT profile distribution for year 1942 .

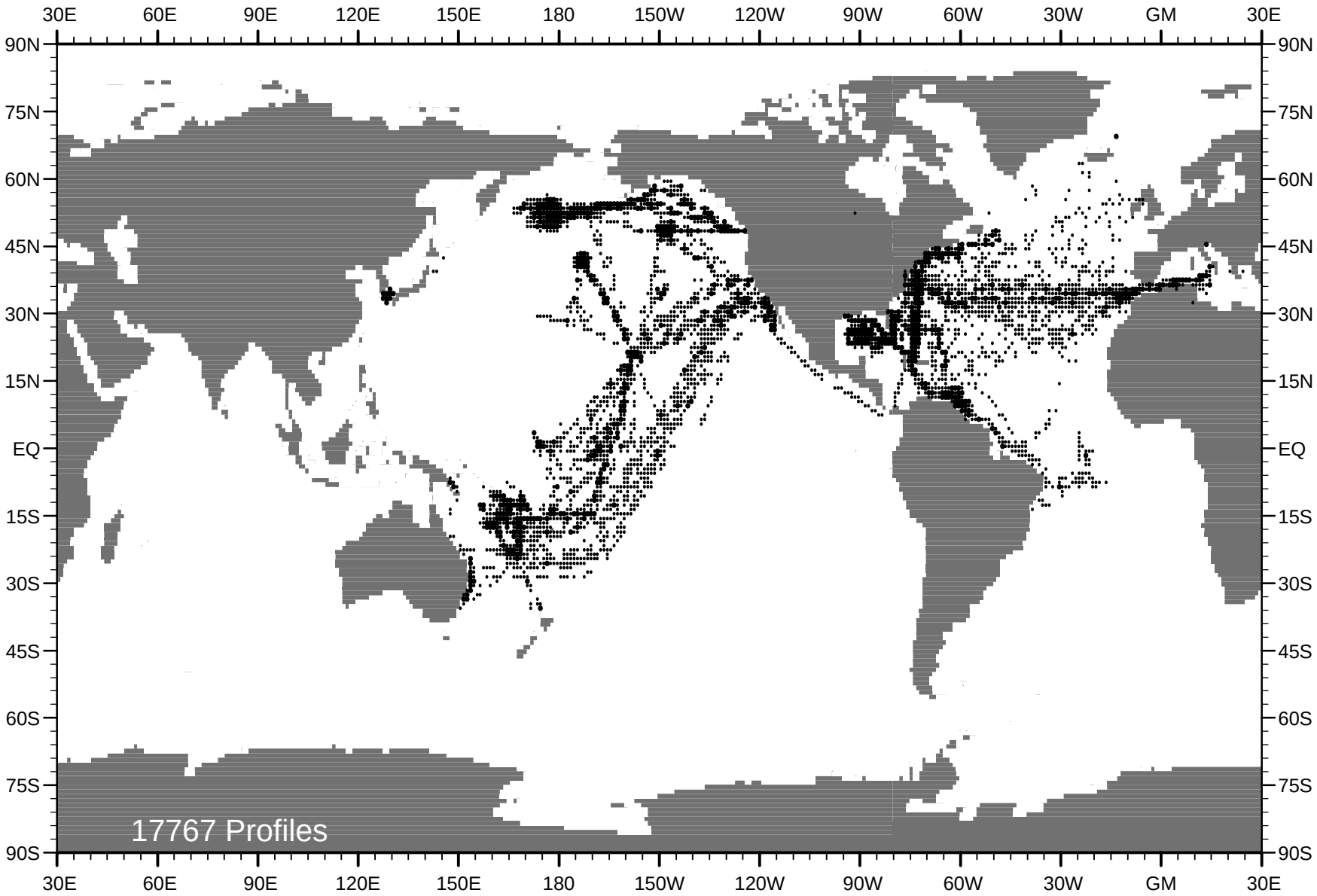

Fig. A3 WOD01 MBT profile distribution for year 1943 .

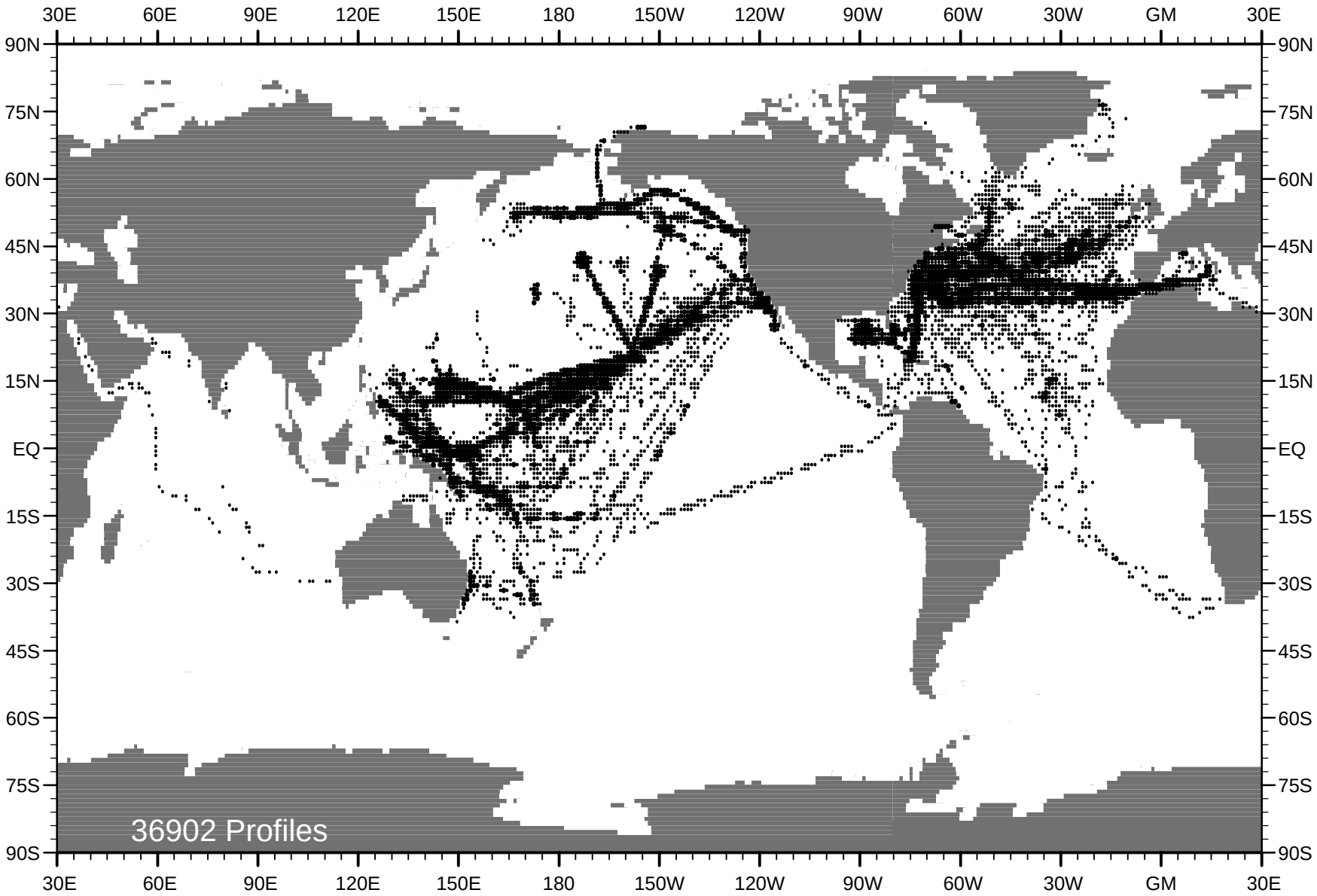

Fig. A4 WOD01 MBT profile distribution for year 1944 .

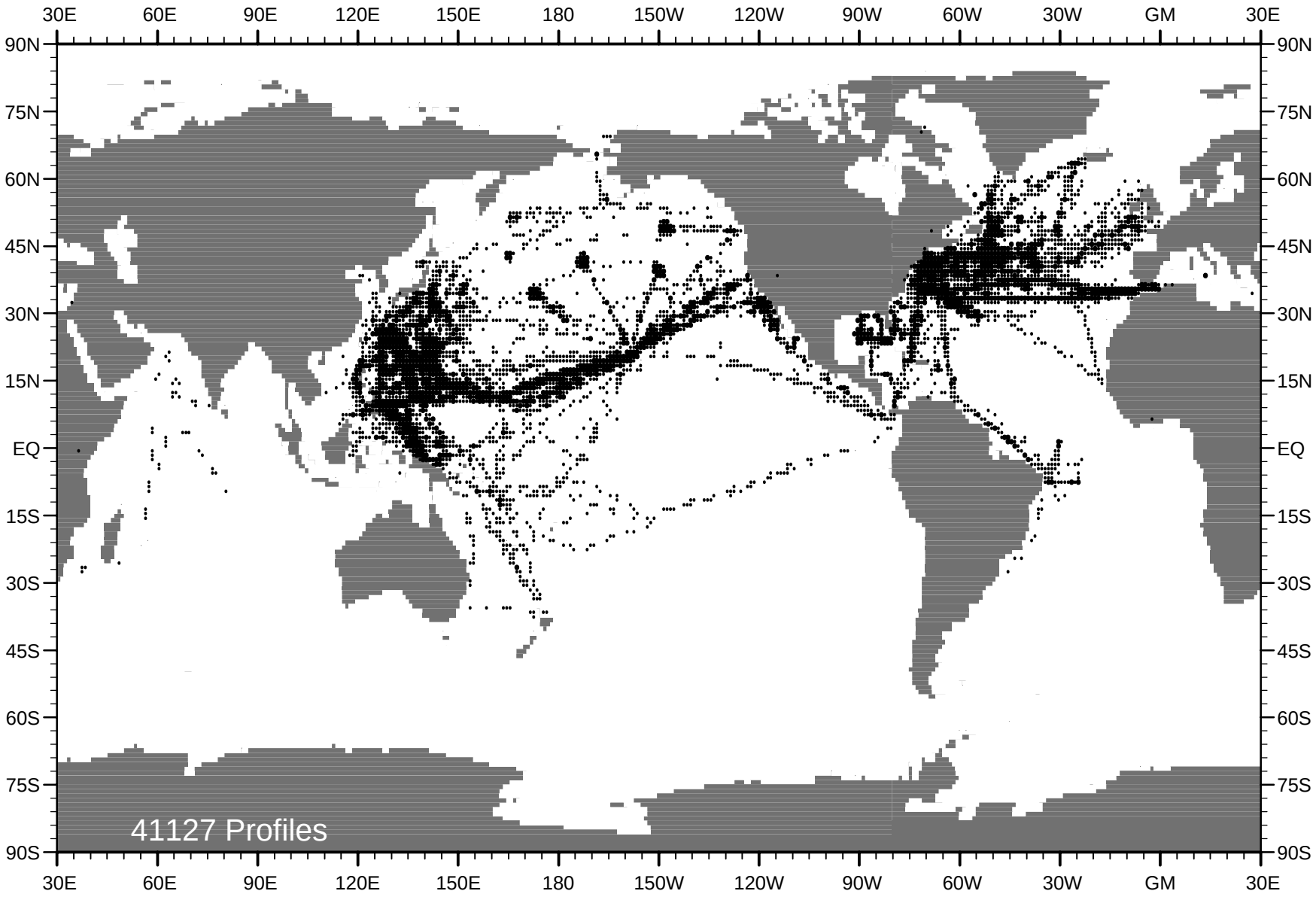

Fig. A5 WOD01 MBT profile distribution for year 1945 .

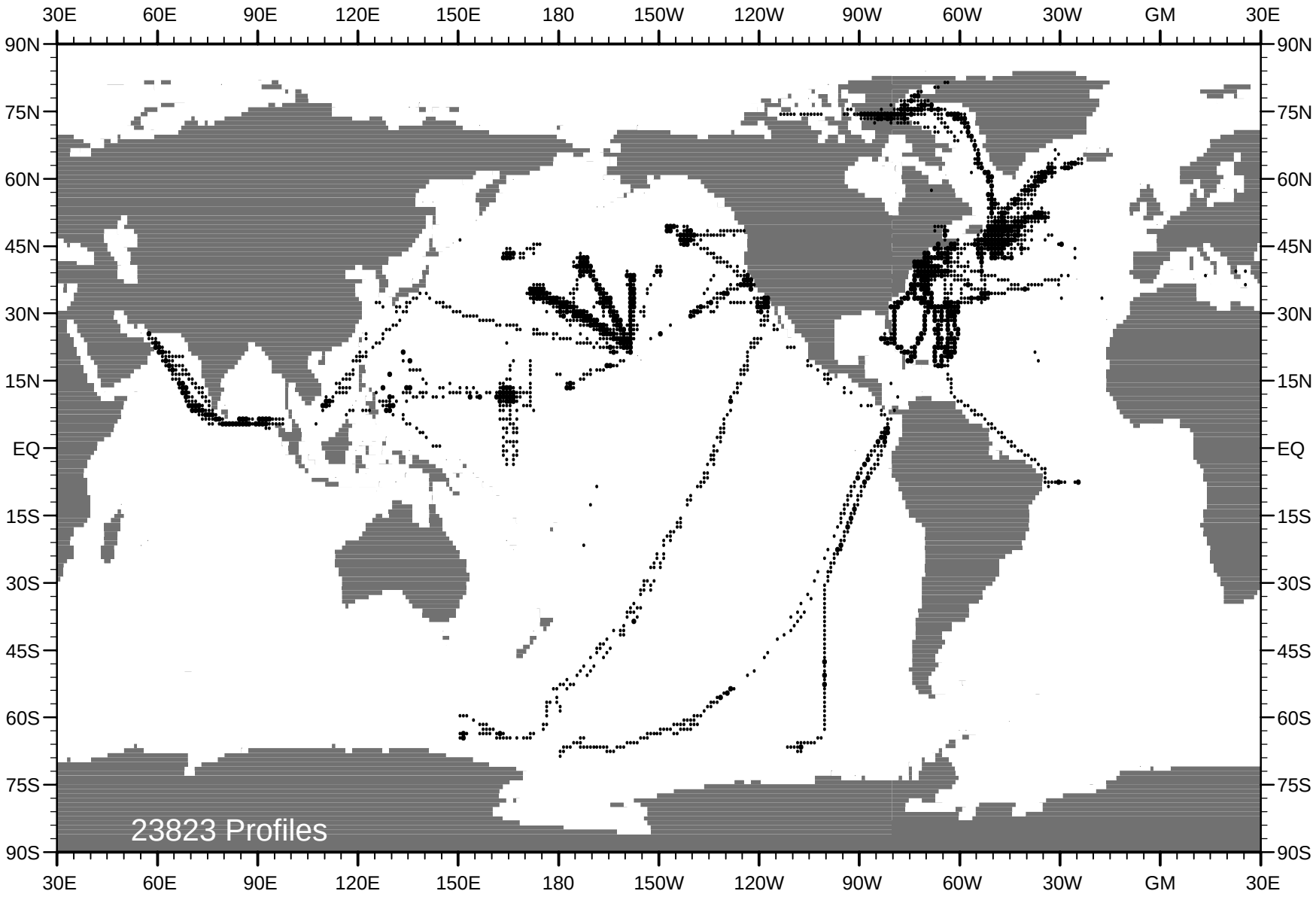

Fig. A6 WOD01 MBT profile distribution for year 1946 .

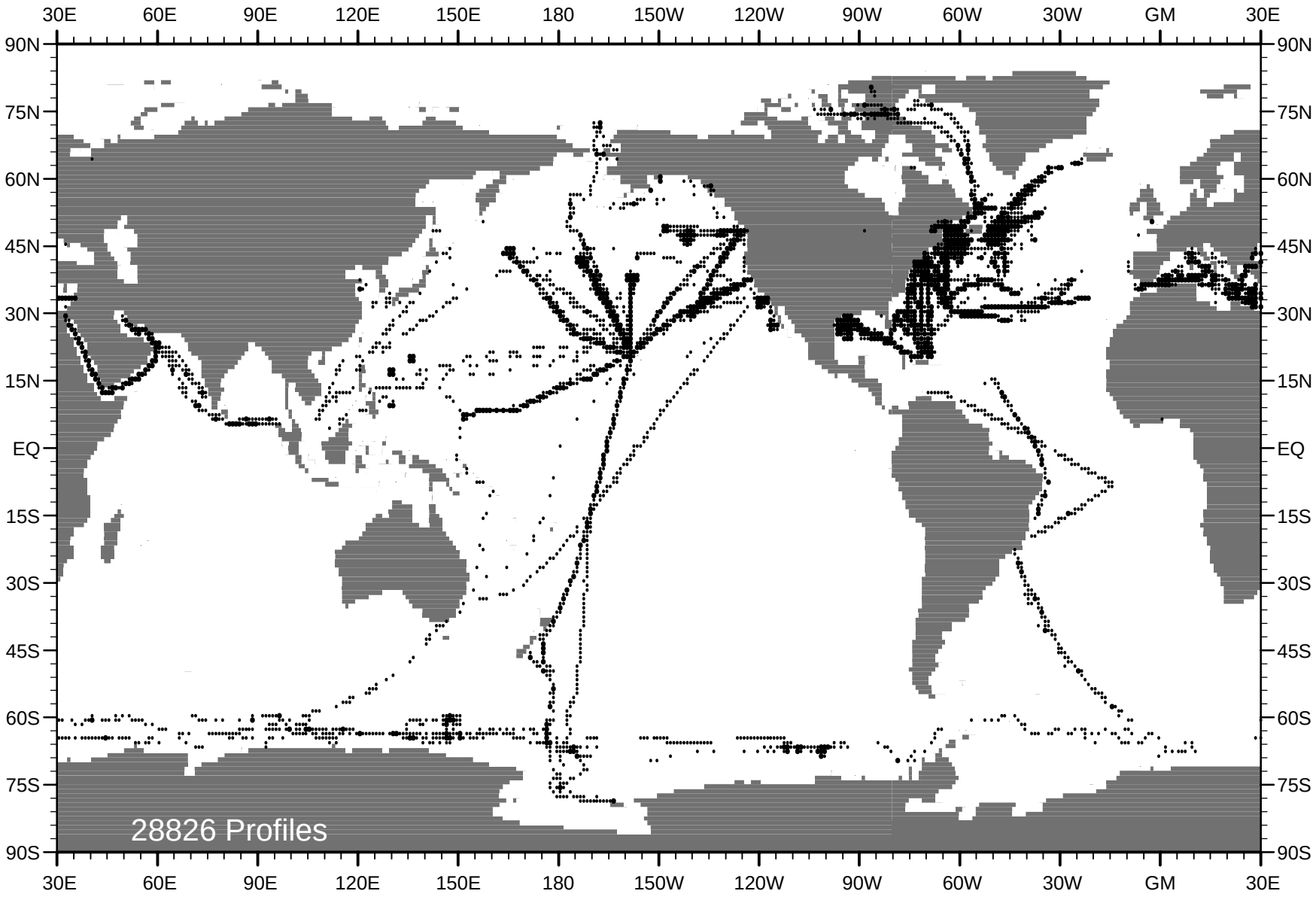

Fig. A7 WOD01 MBT profile distribution for year 1947 .

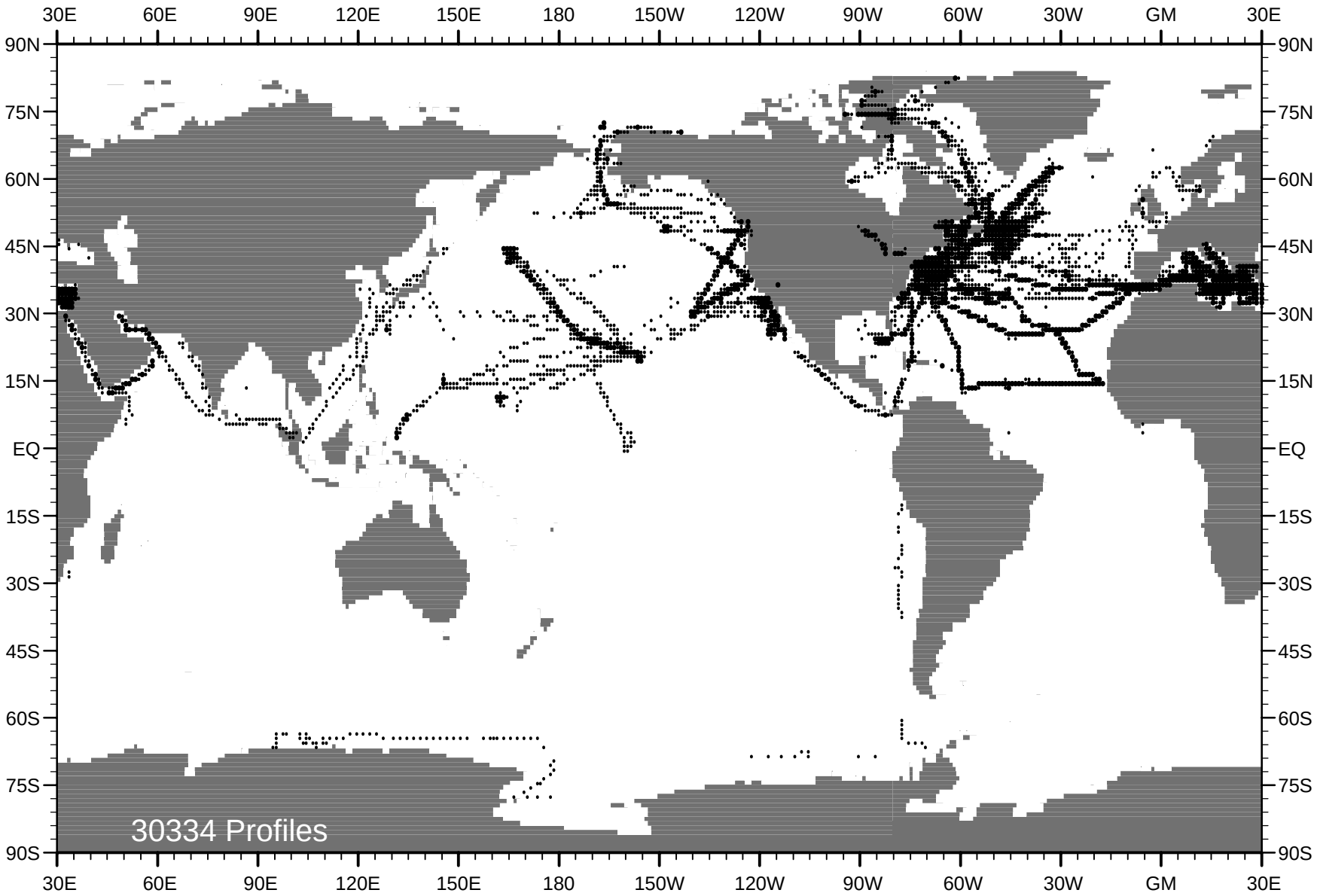

Fig. A8 WOD01 MBT profile distribution for year 1948 .

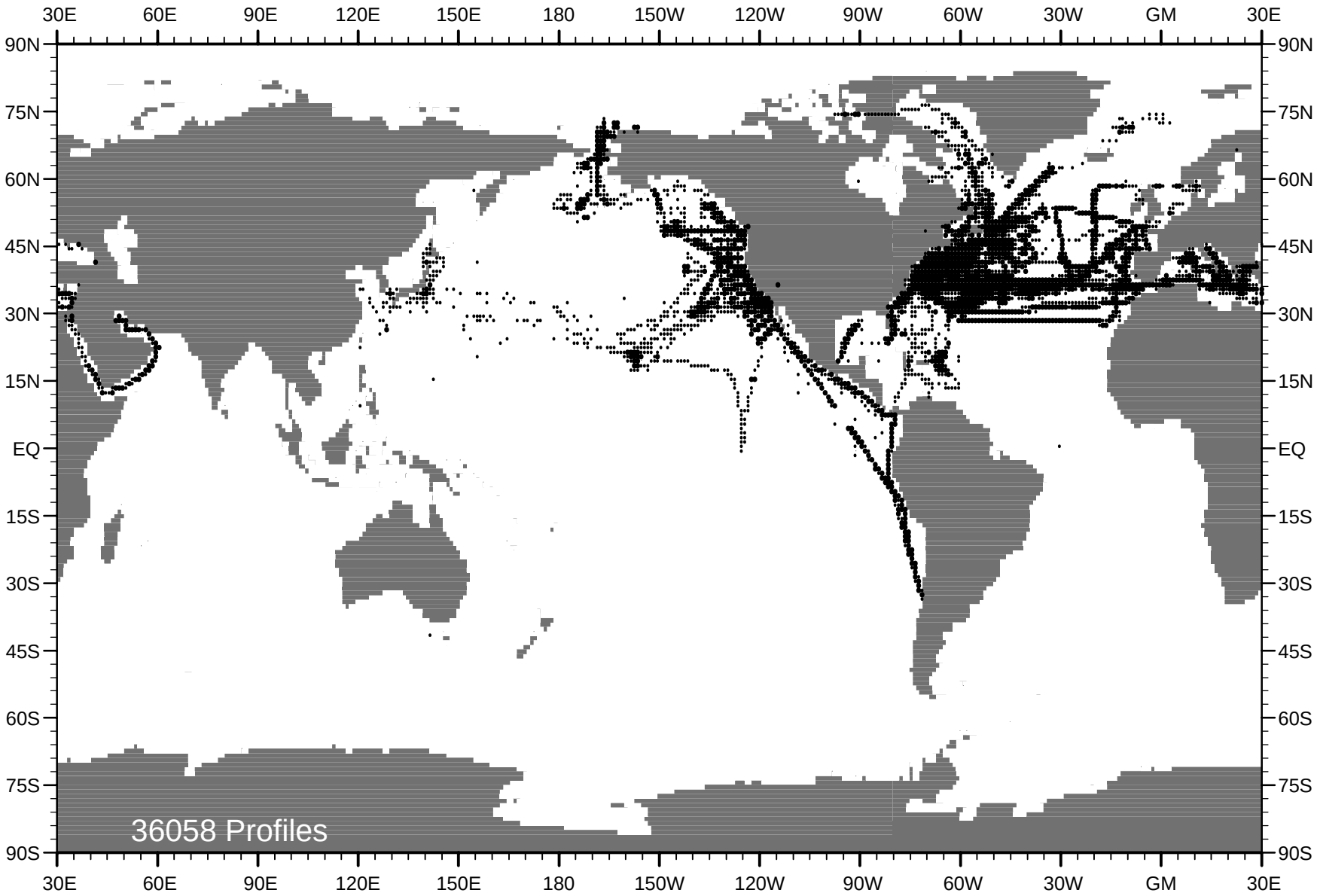

Fig. A9 WOD01 MBT profile distribution for year 1949 .

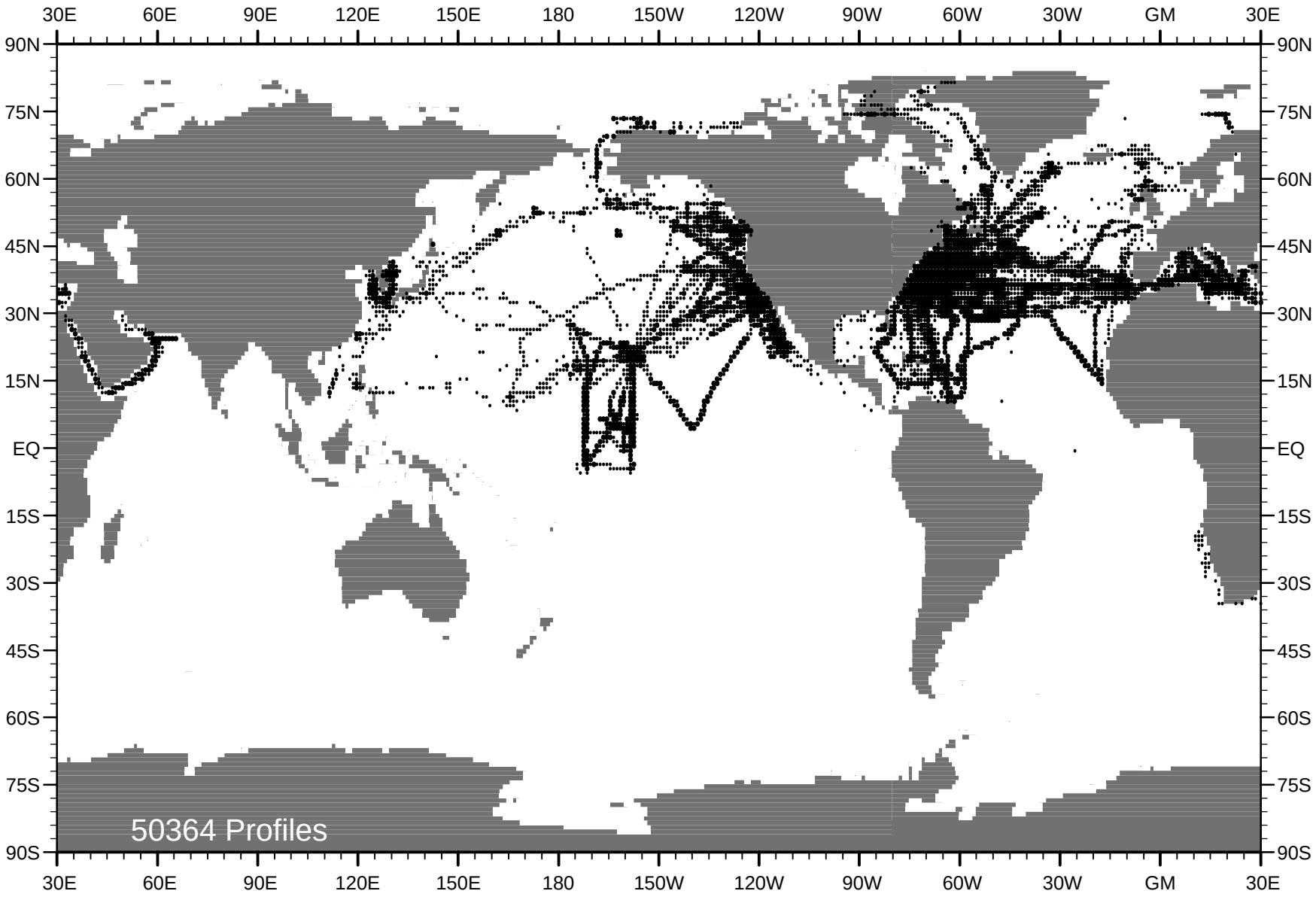

Fig. A10 WOD01 MBT profile distribution for year 1950 .

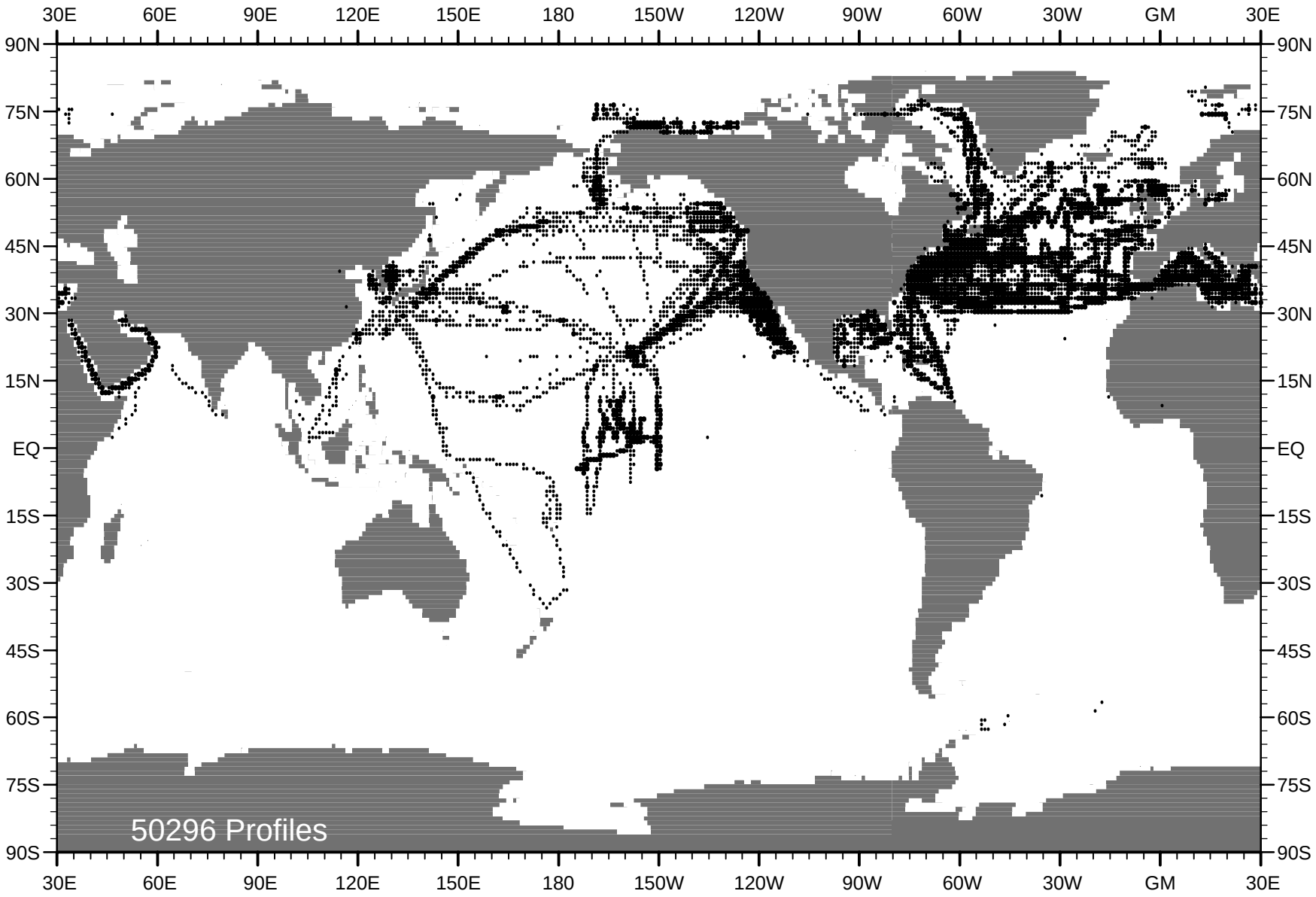

Fig. A11 WOD01 MBT profile distribution for year 1951 .

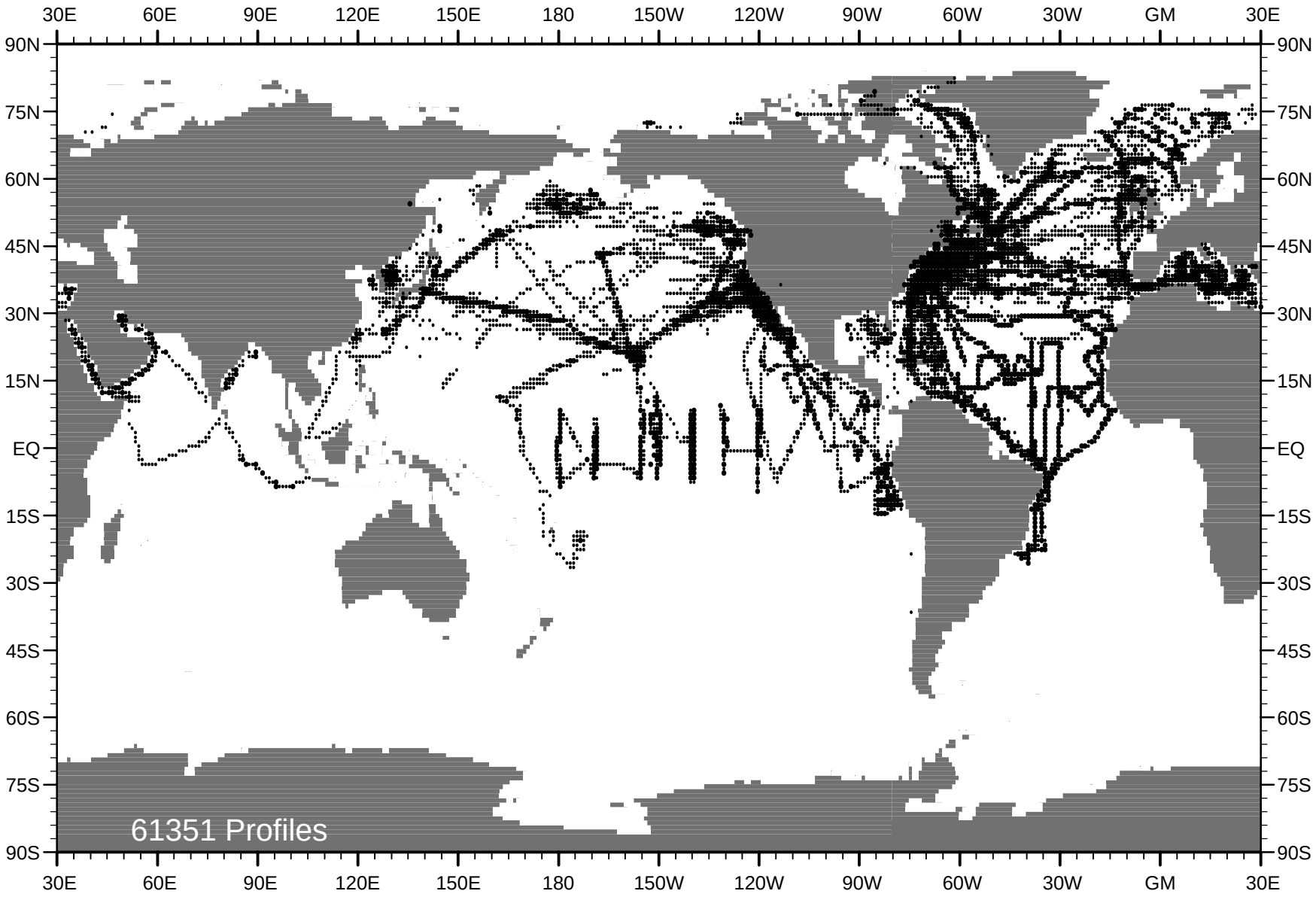

Fig. A12 WOD01 MBT profile distribution for year 1952 .

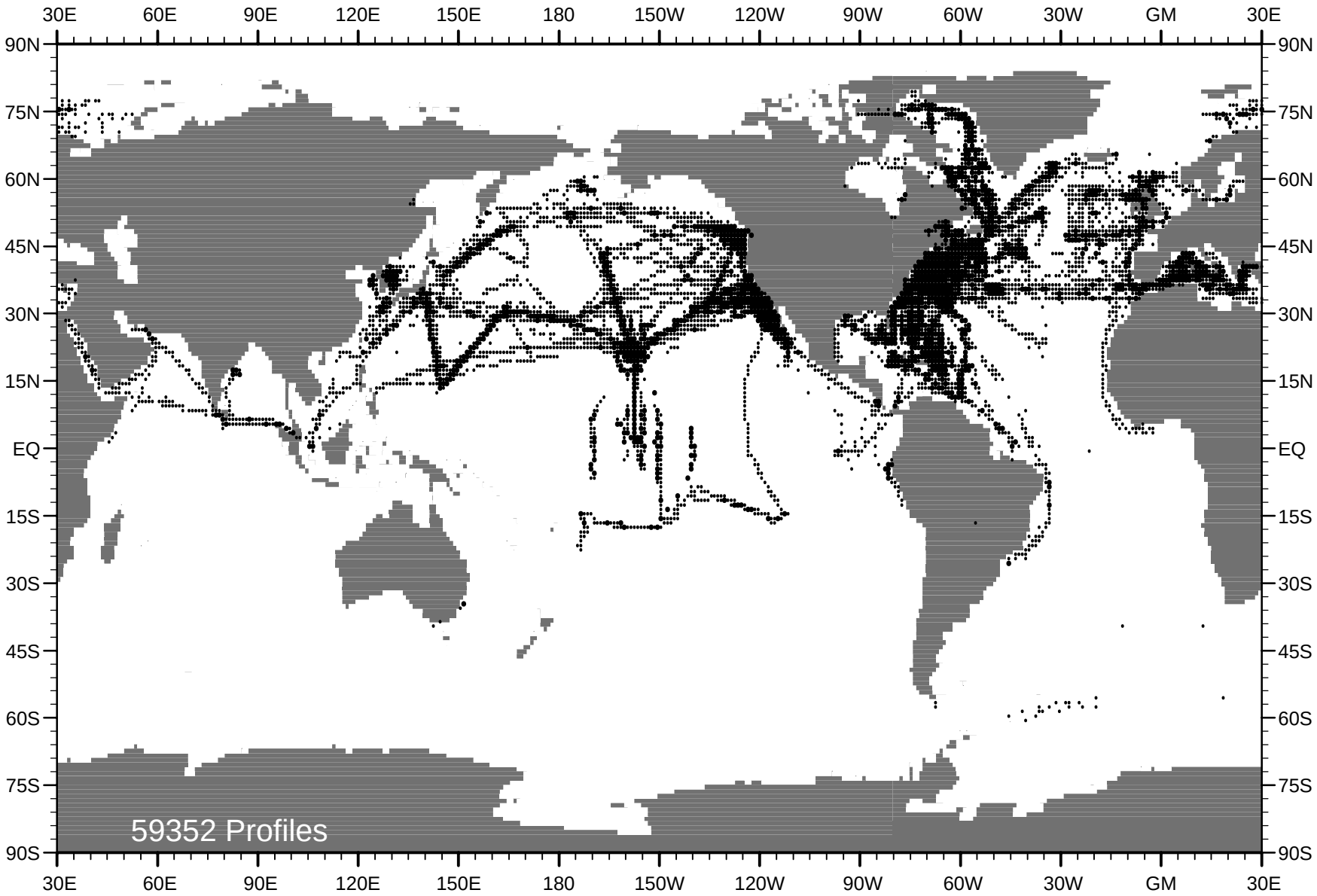

Fig. A13 WOD01 MBT profile distribution for year 1953 .

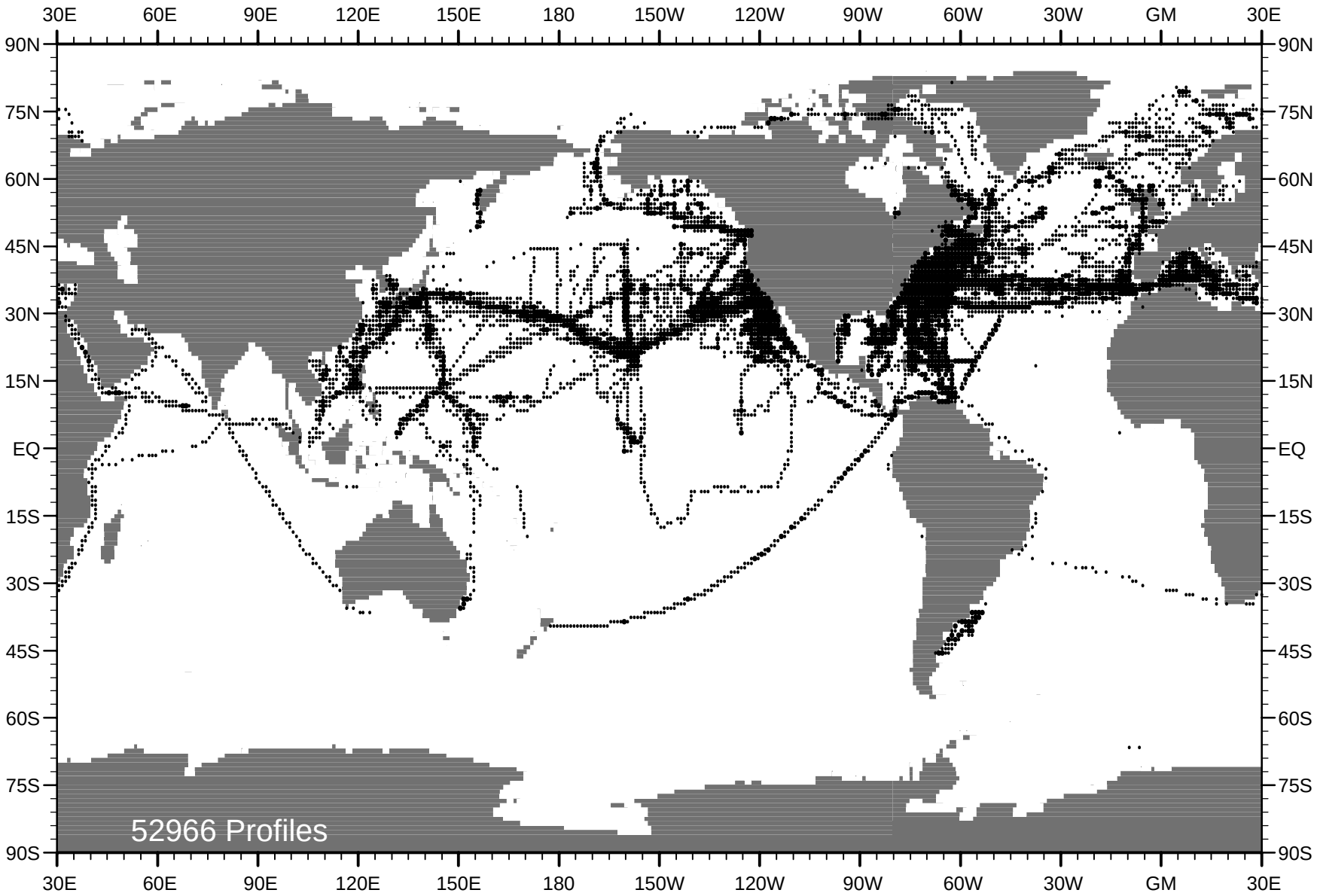

Fig. A14 WOD01 MBT profile distribution for year 1954 .

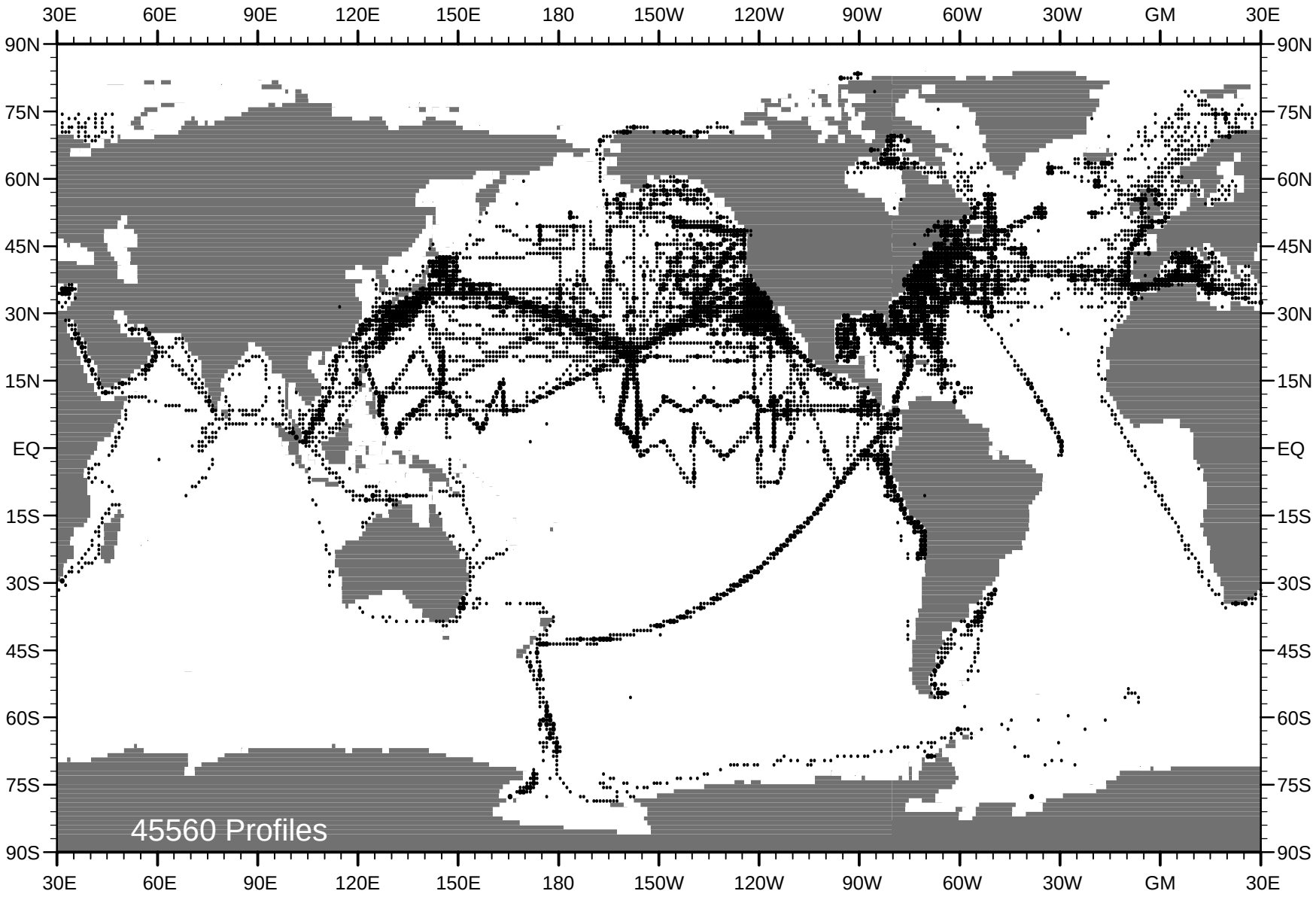

Fig. A15 WOD01 MBT profile distribution for year 1955 .

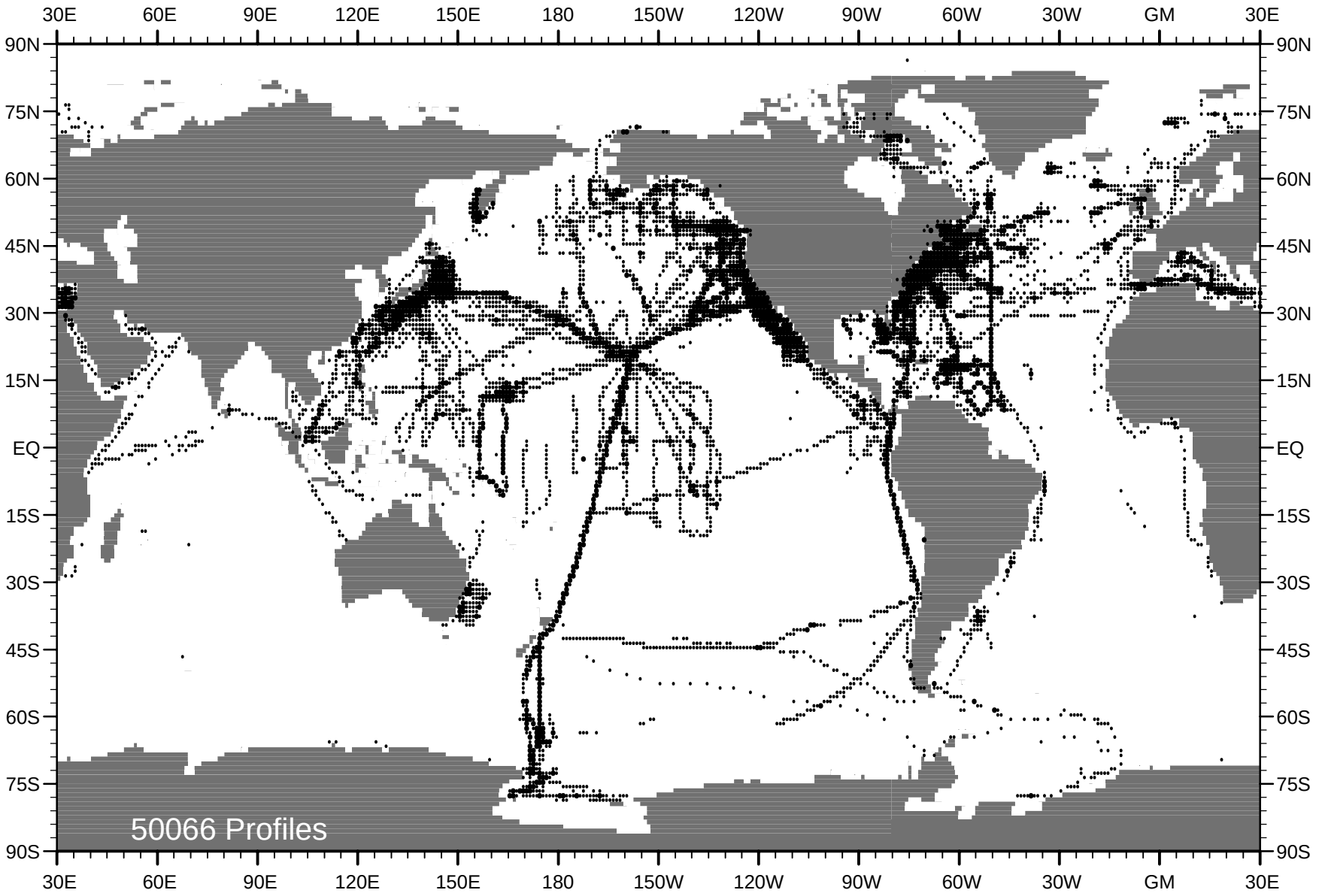

Fig. A16 WOD01 MBT profile distribution for year 1956 .

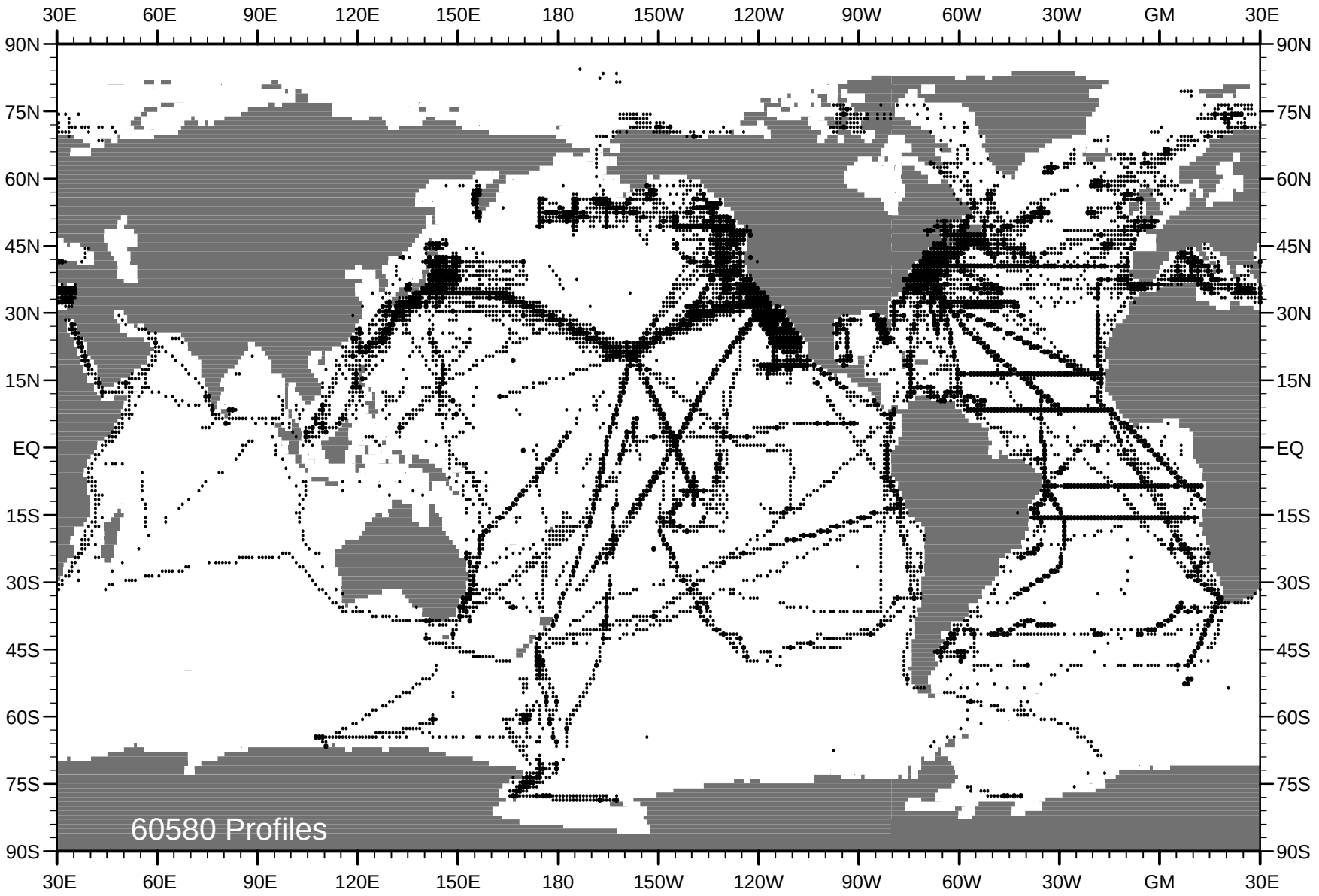

Fig. A17 WOD01 MBT profile distribution for year 1957 .

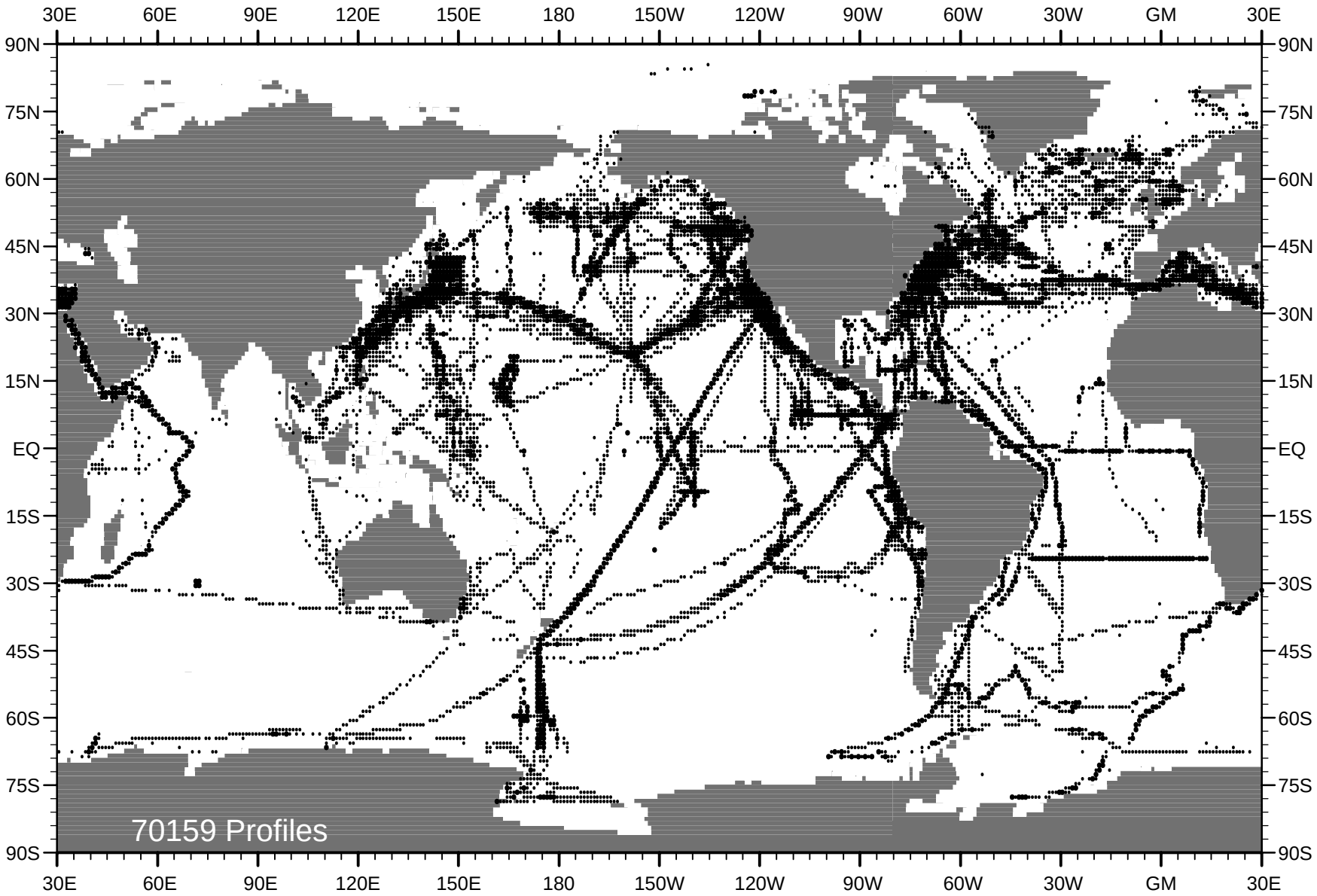

Fig. A18 WOD01 MBT profile distribution for year 1958 .

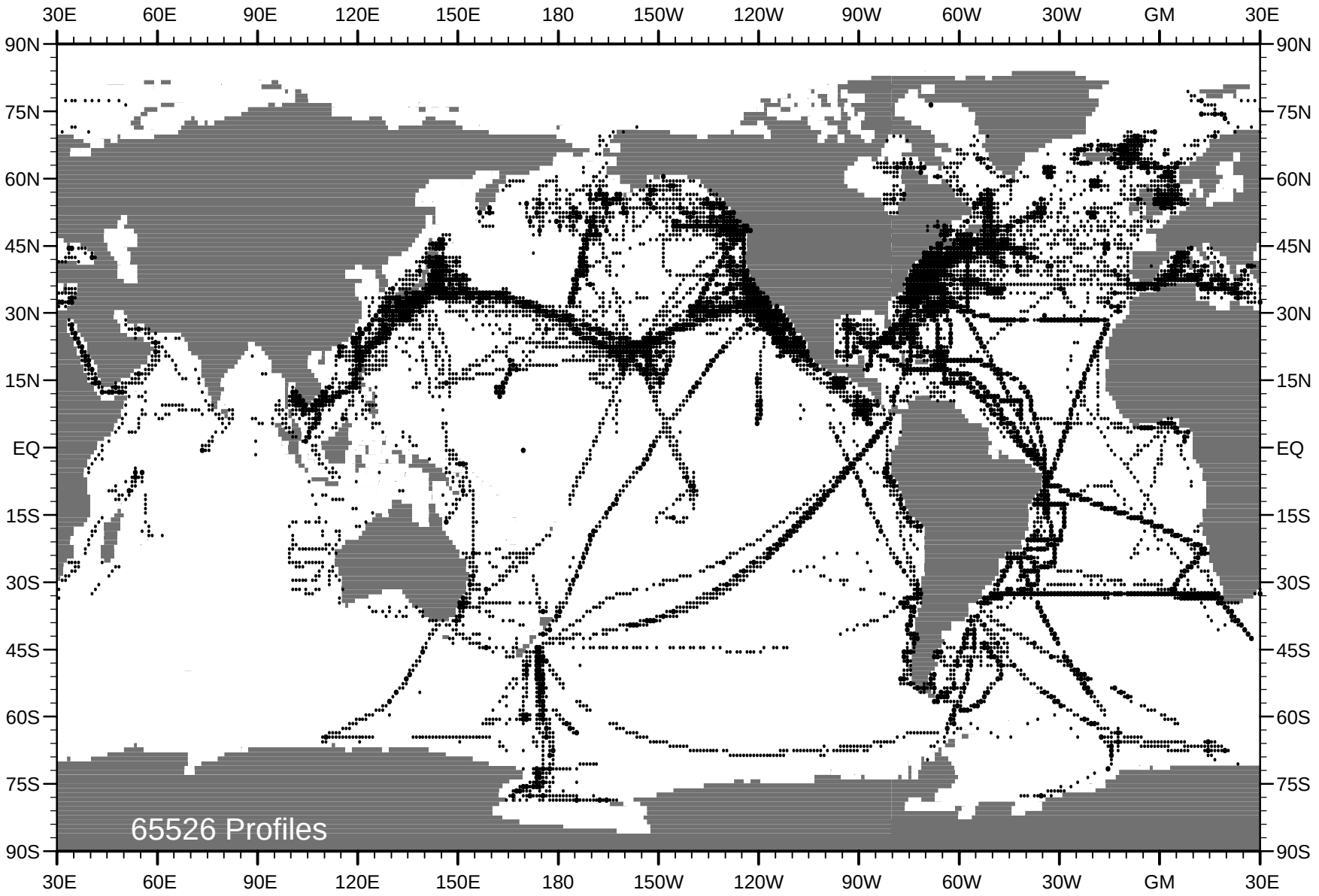

Fig. A19 WOD01 MBT profile distribution for year 1959 .

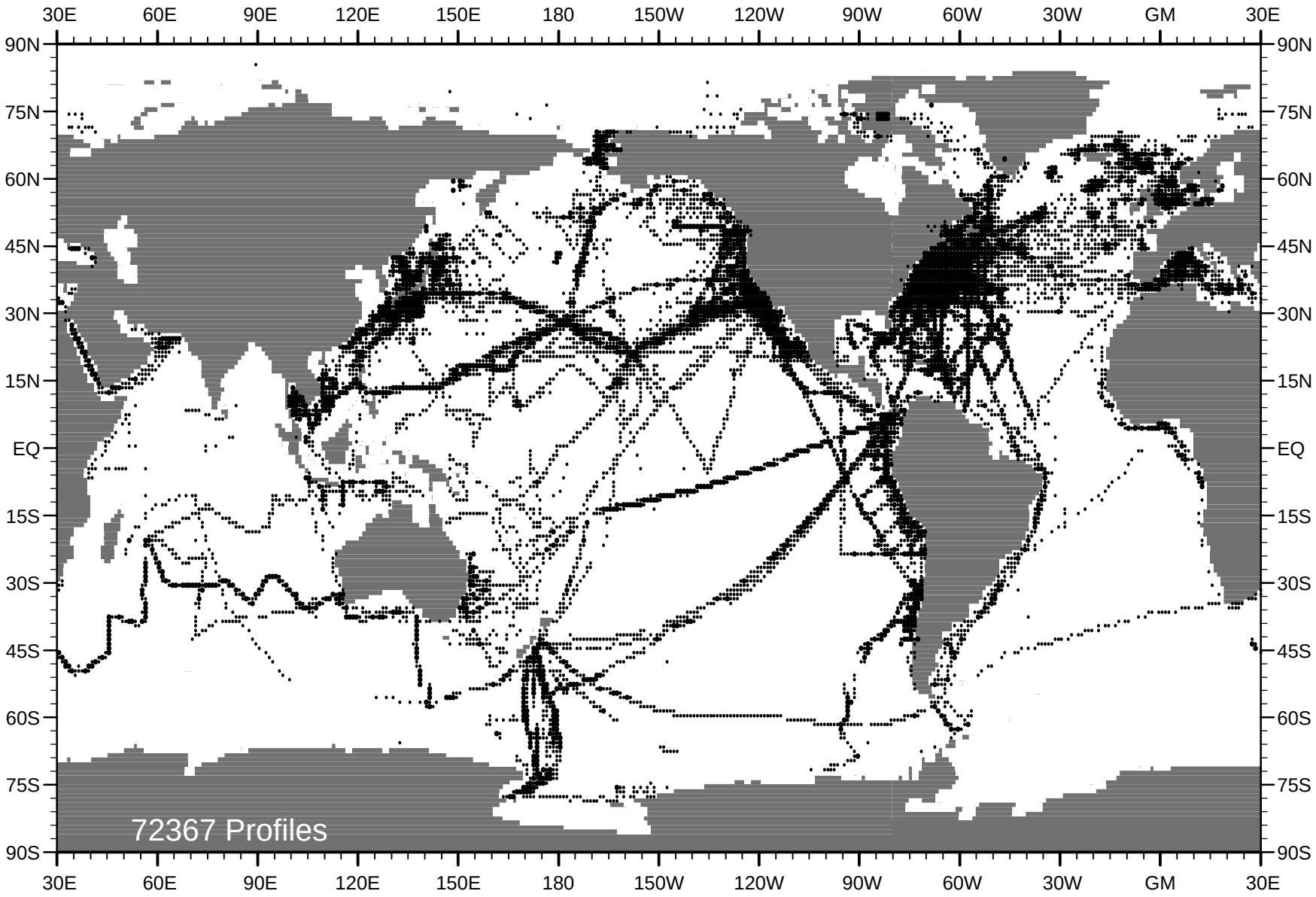

Fig. A20 WOD01 MBT profile distribution for year 1960 .

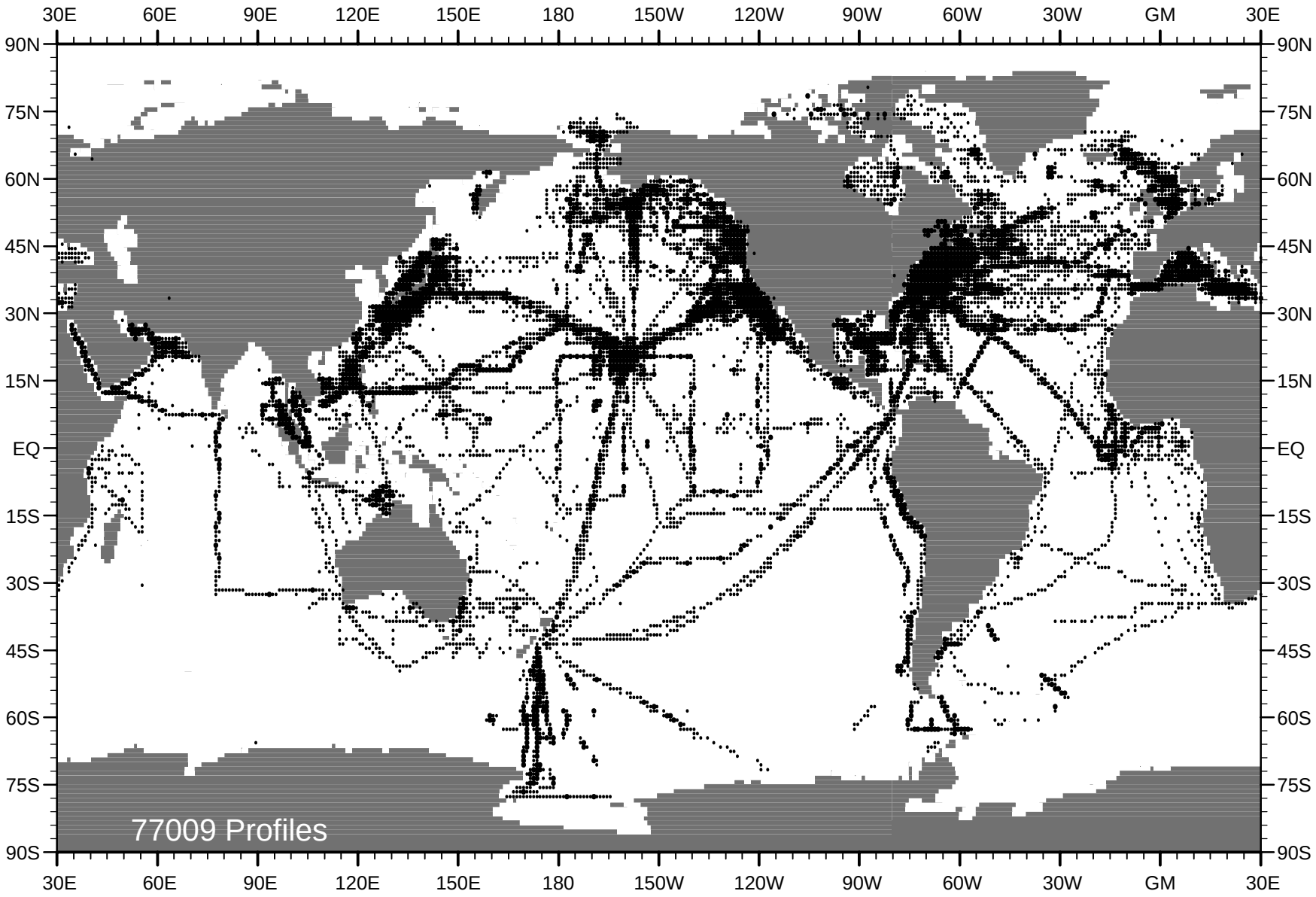

Fig. A21 WOD01 MBT profile distribution for year 1961 .

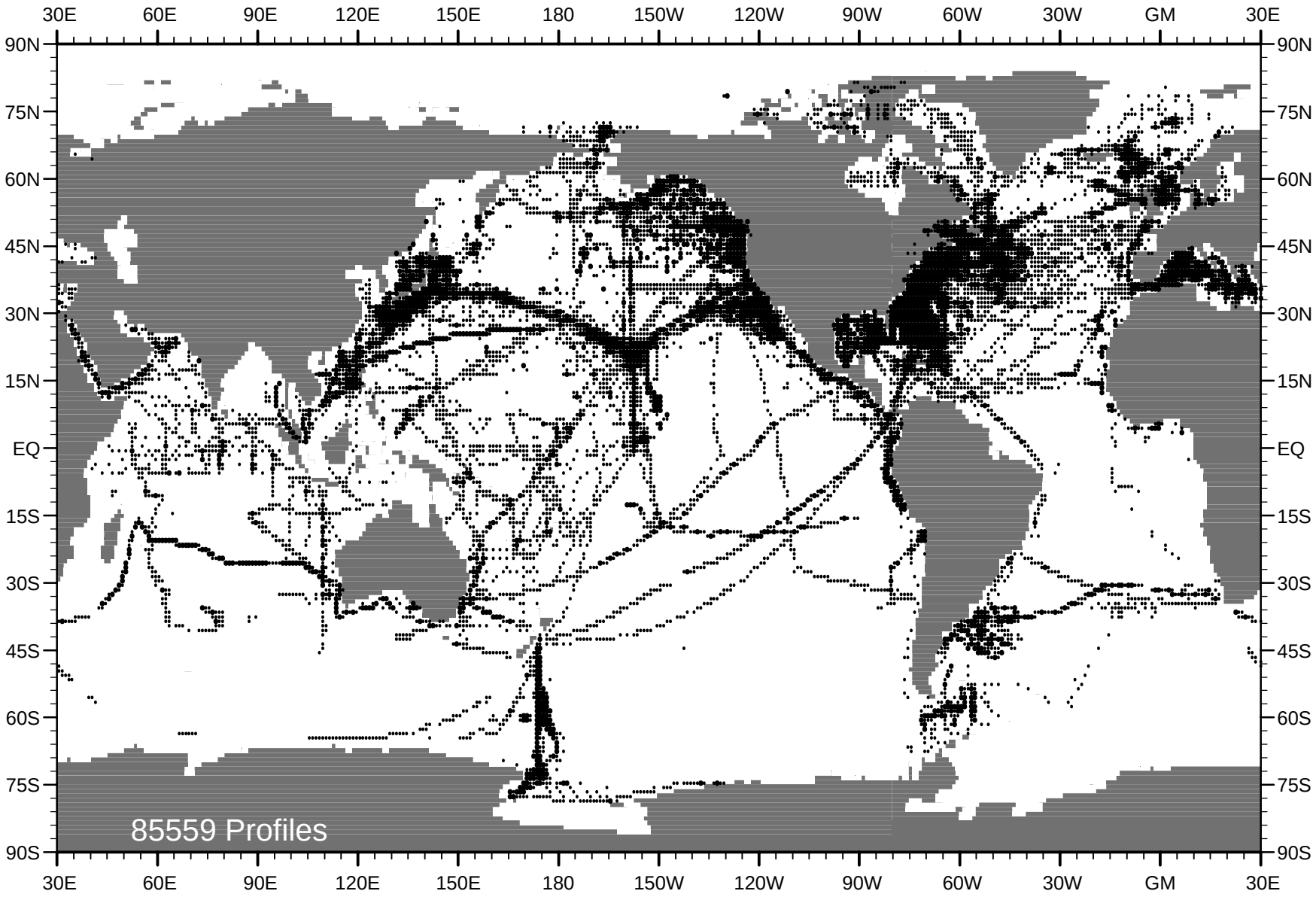

Fig. A22 WOD01 MBT profile distribution for year 1962 .

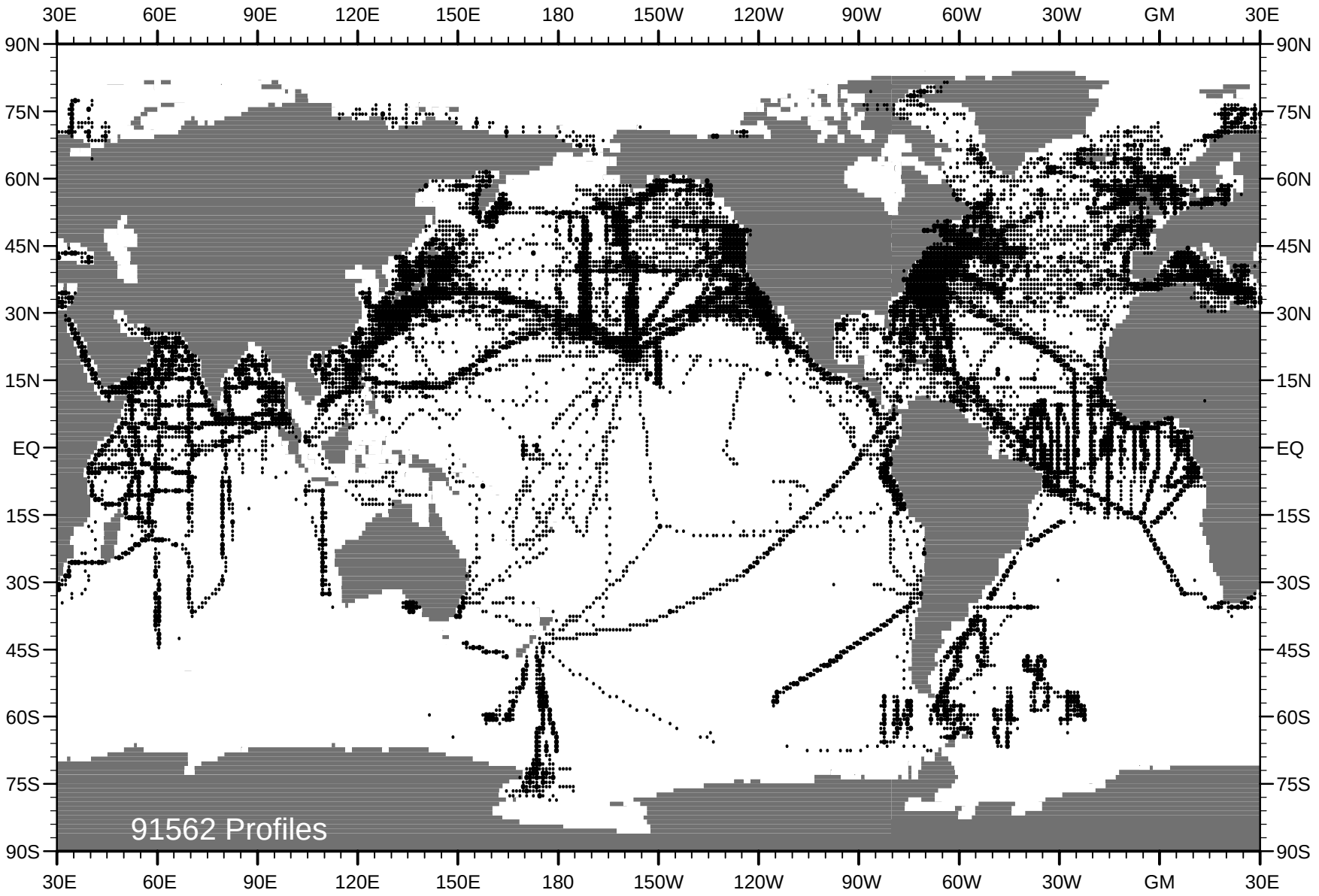

Fig. A23 WOD01 MBT profile distribution for year 1963 .

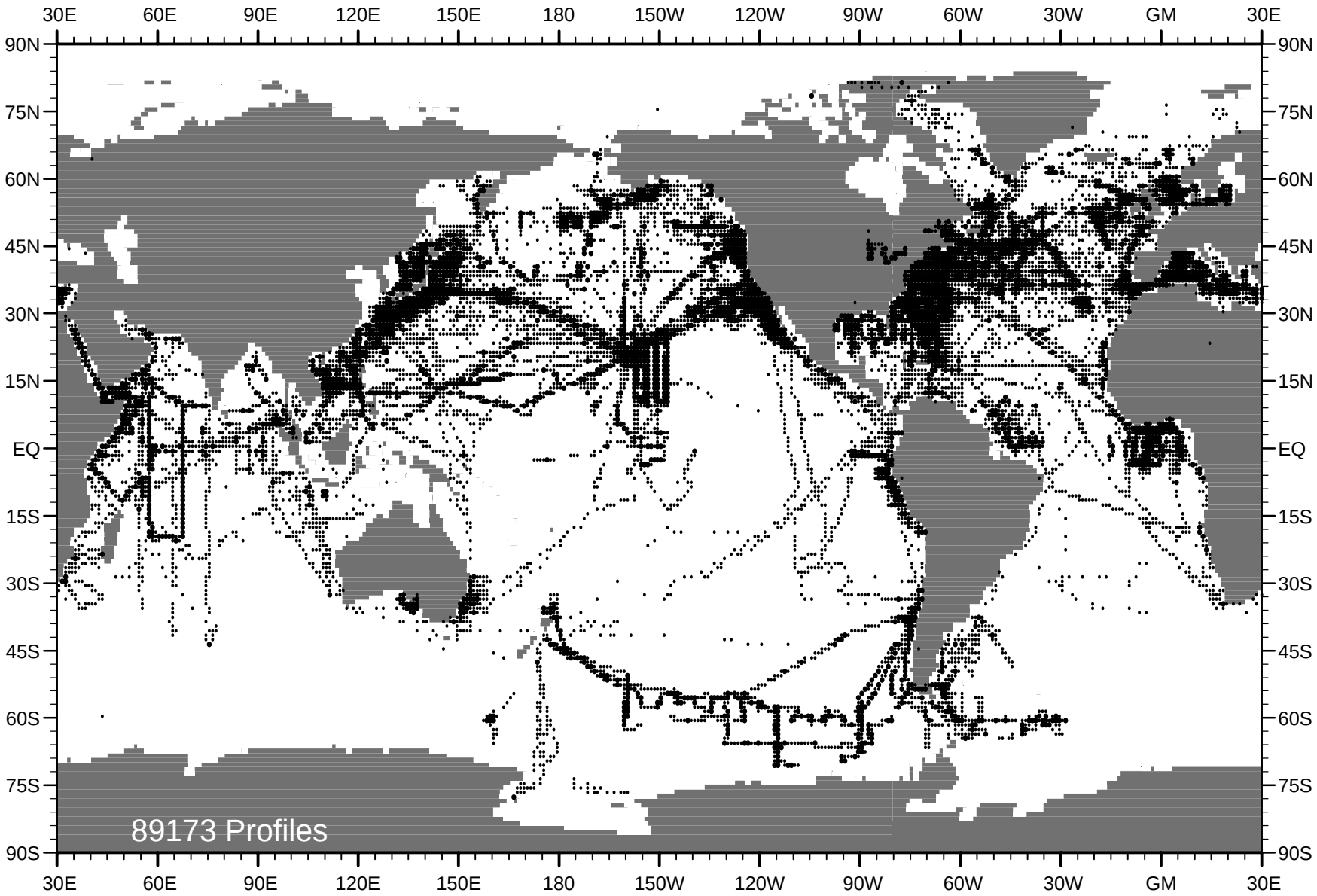

Fig. A24 WOD01 MBT profile distribution for year 1964 .

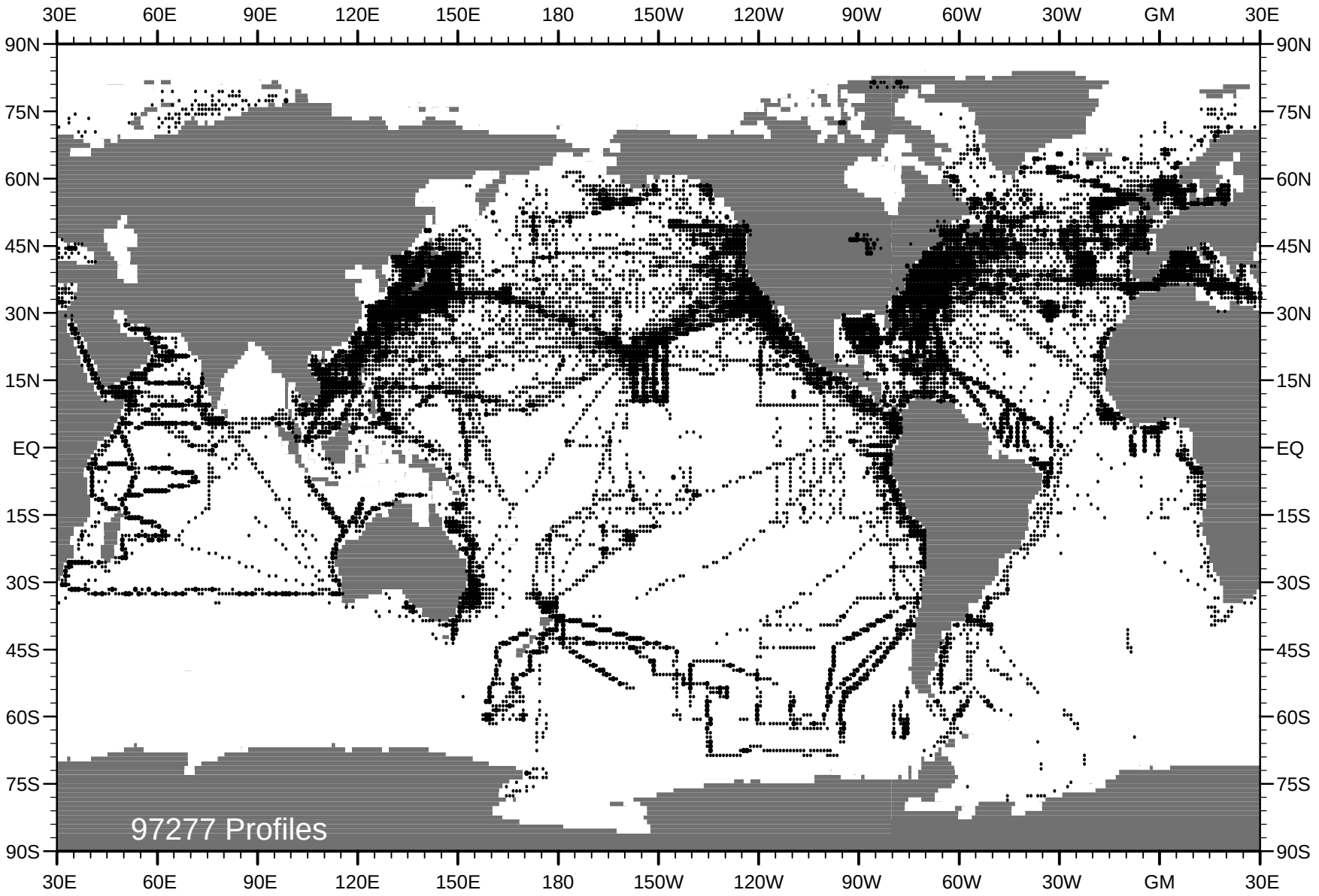

Fig. A25 WOD01 MBT profile distribution for year 1965 .

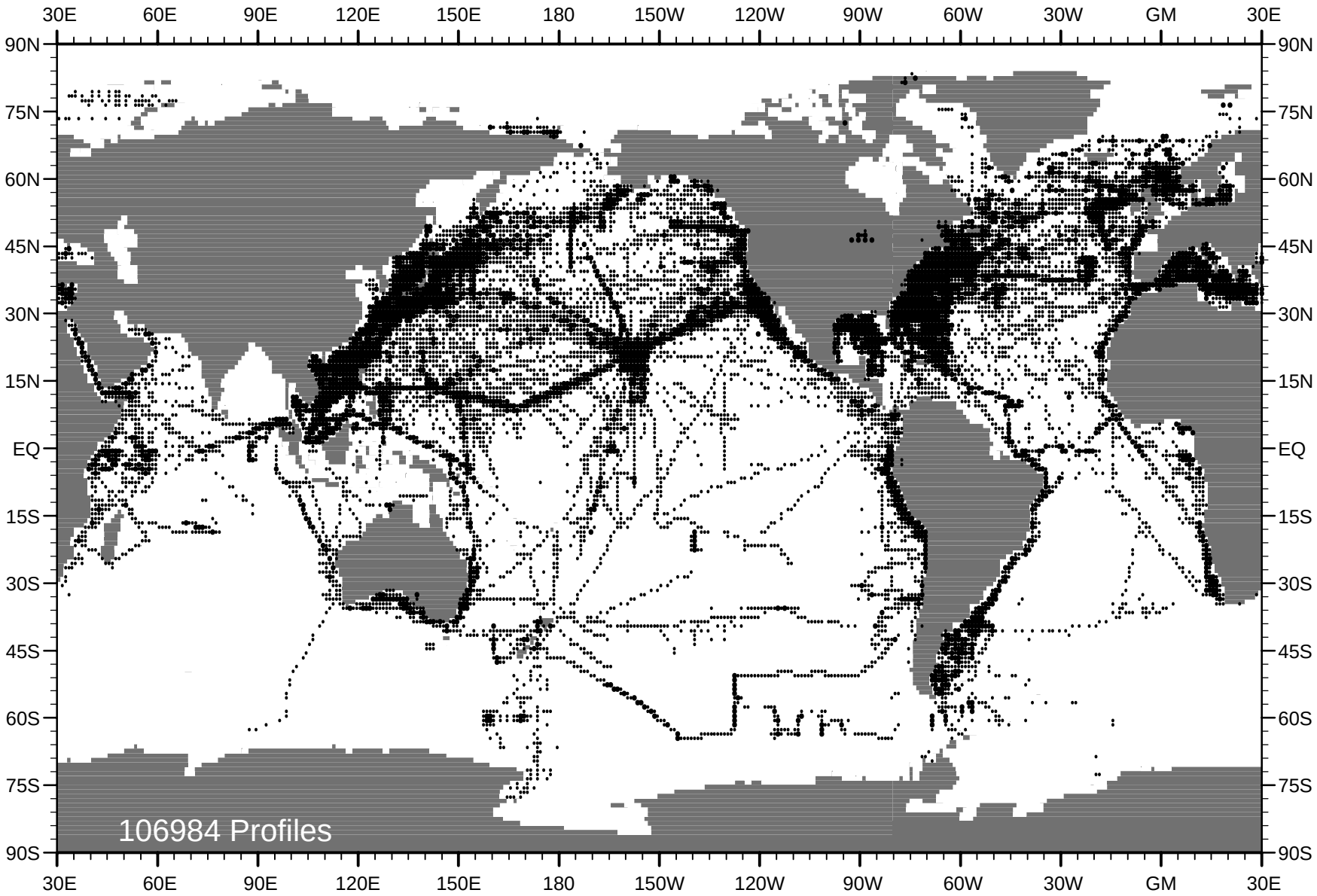

Fig. A26 WOD01 MBT profile distribution for year 1966 .

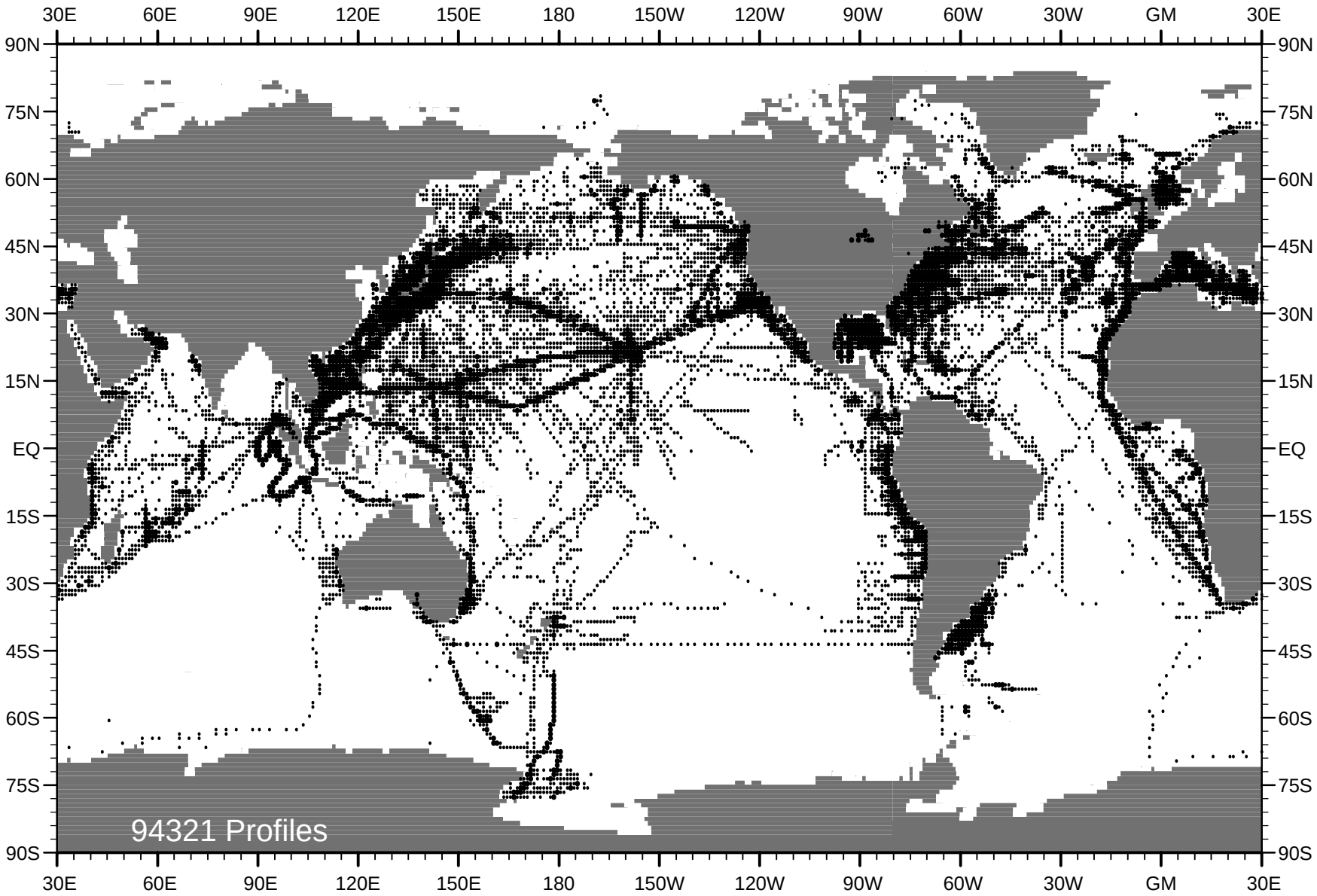

Fig. A27 WOD01 MBT profile distribution for year 1967 .

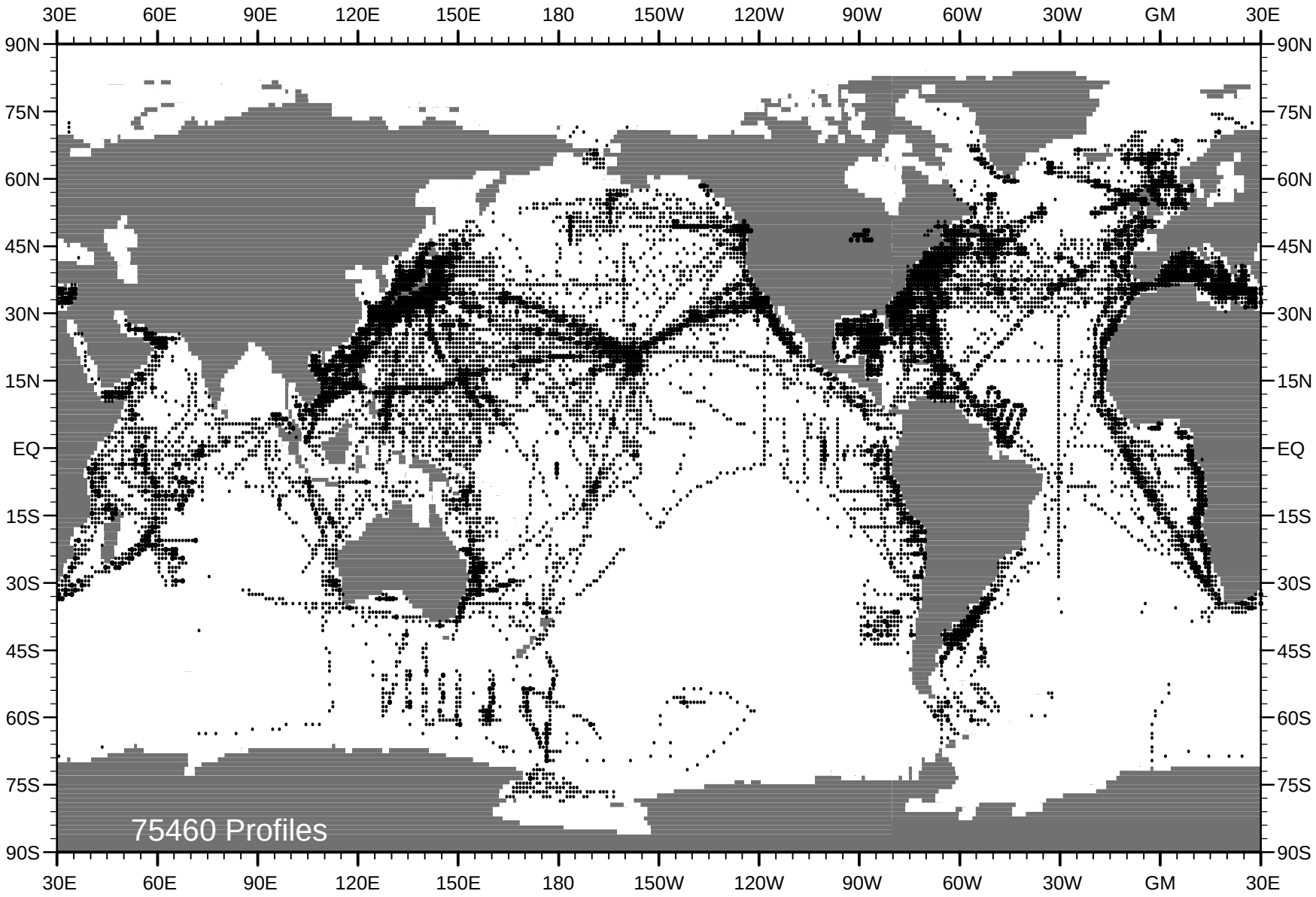

Fig. A28 WOD01 MBT profile distribution for year 1968 .

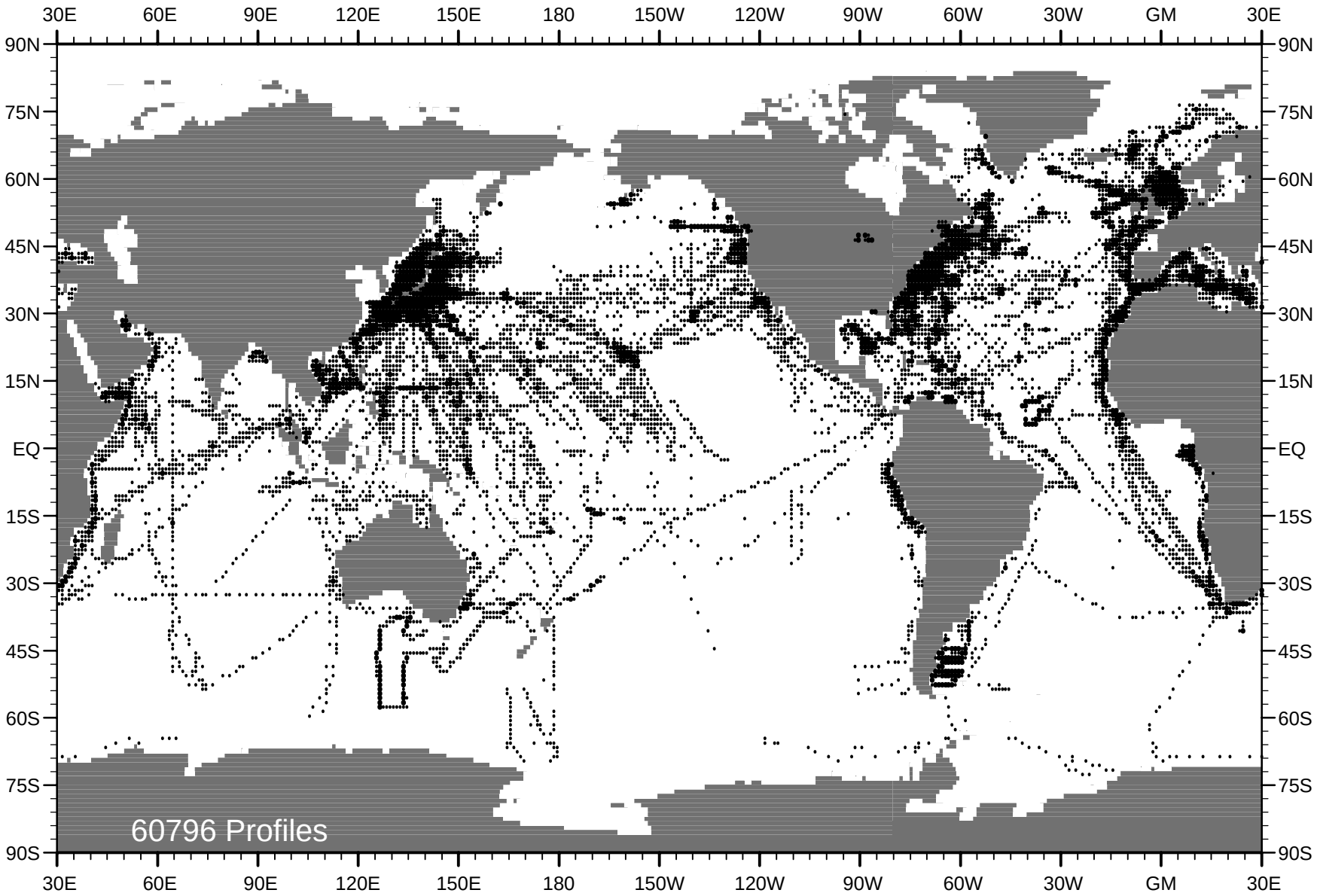

Fig. A29 WOD01 MBT profile distribution for year 1969 .

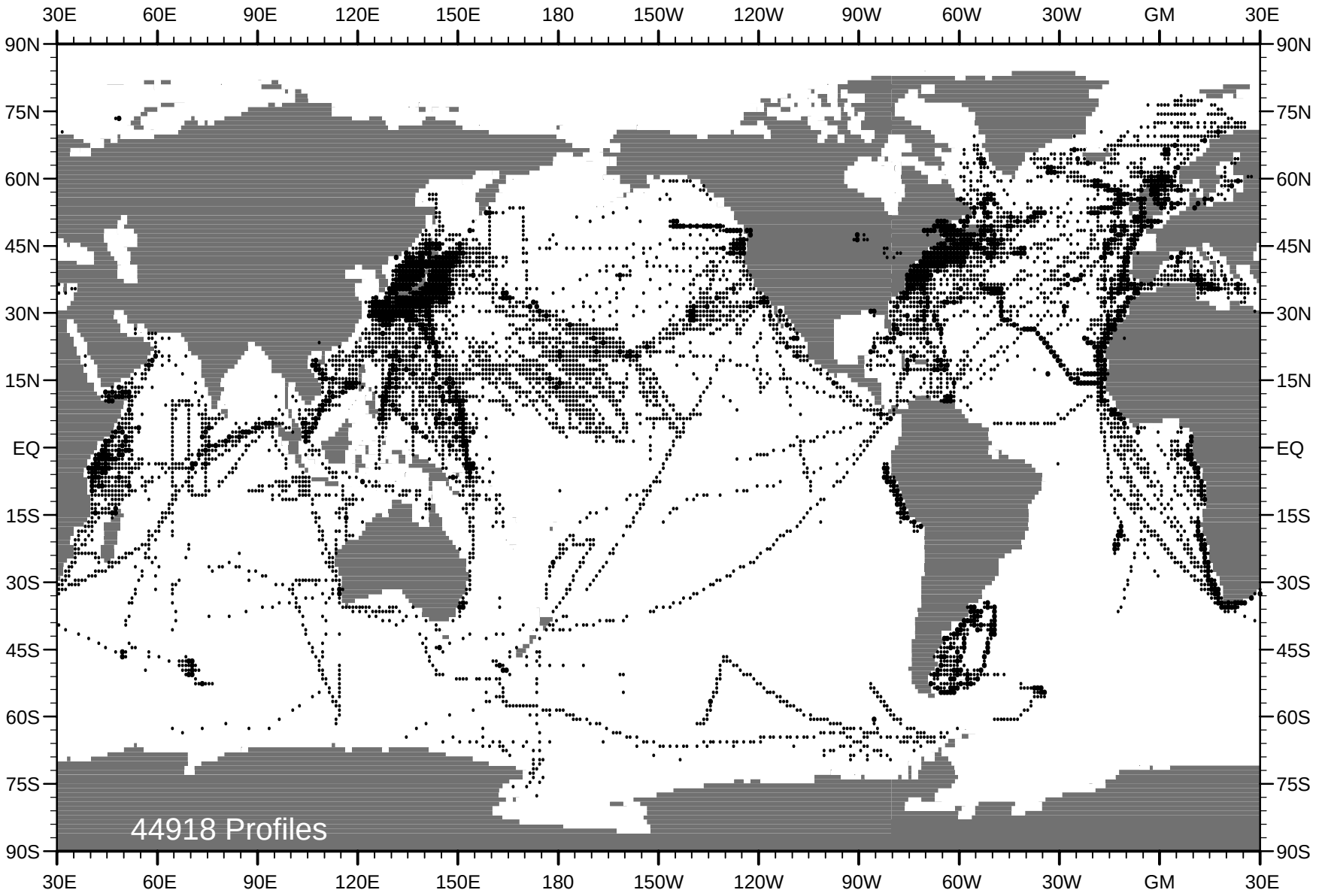

Fig. A30 WOD01 MBT profile distribution for year 1970 .

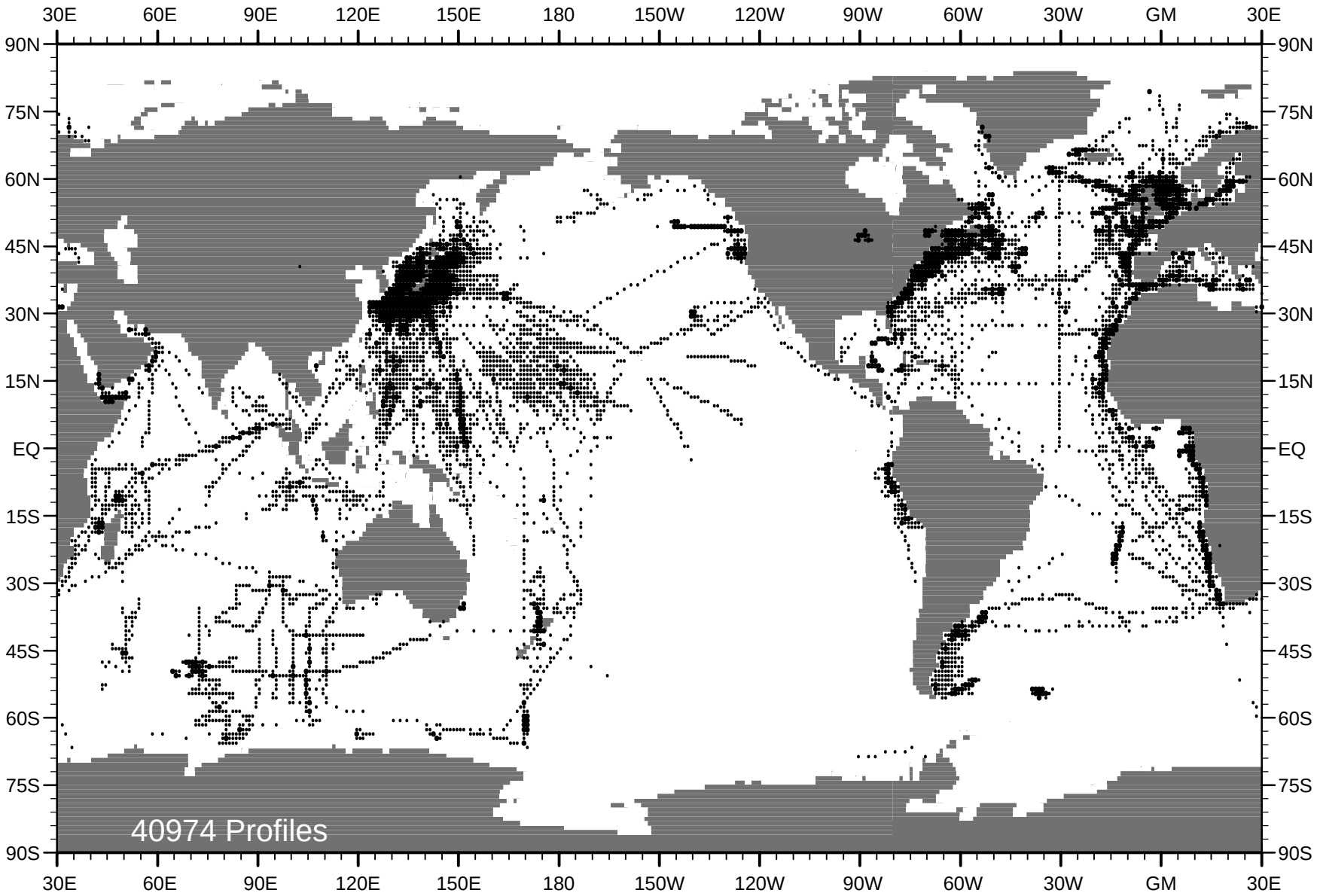

Fig. A31 WOD01 MBT profile distribution for year 1971 .

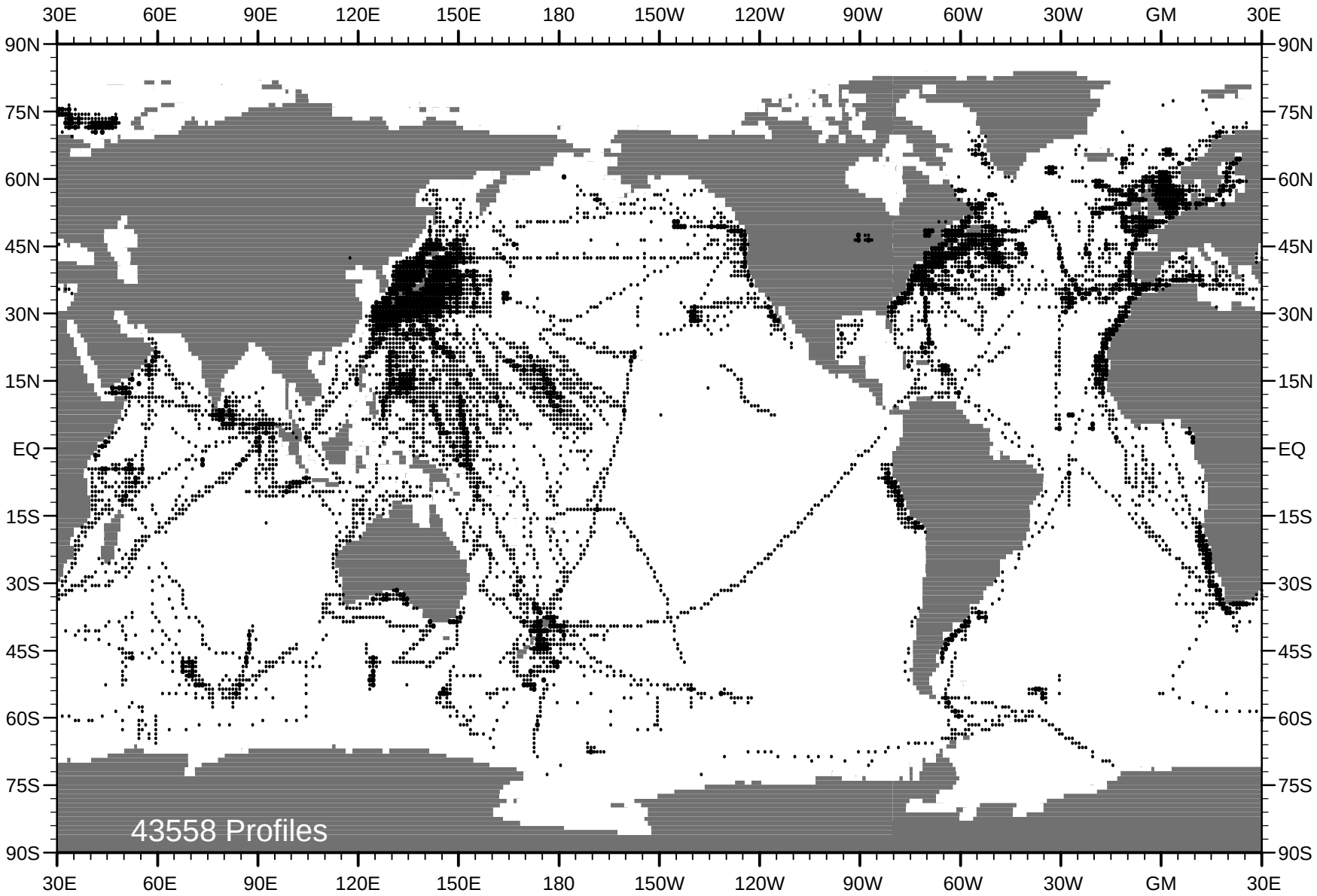

Fig. A32 WOD01 MBT profile distribution for year 1972 .

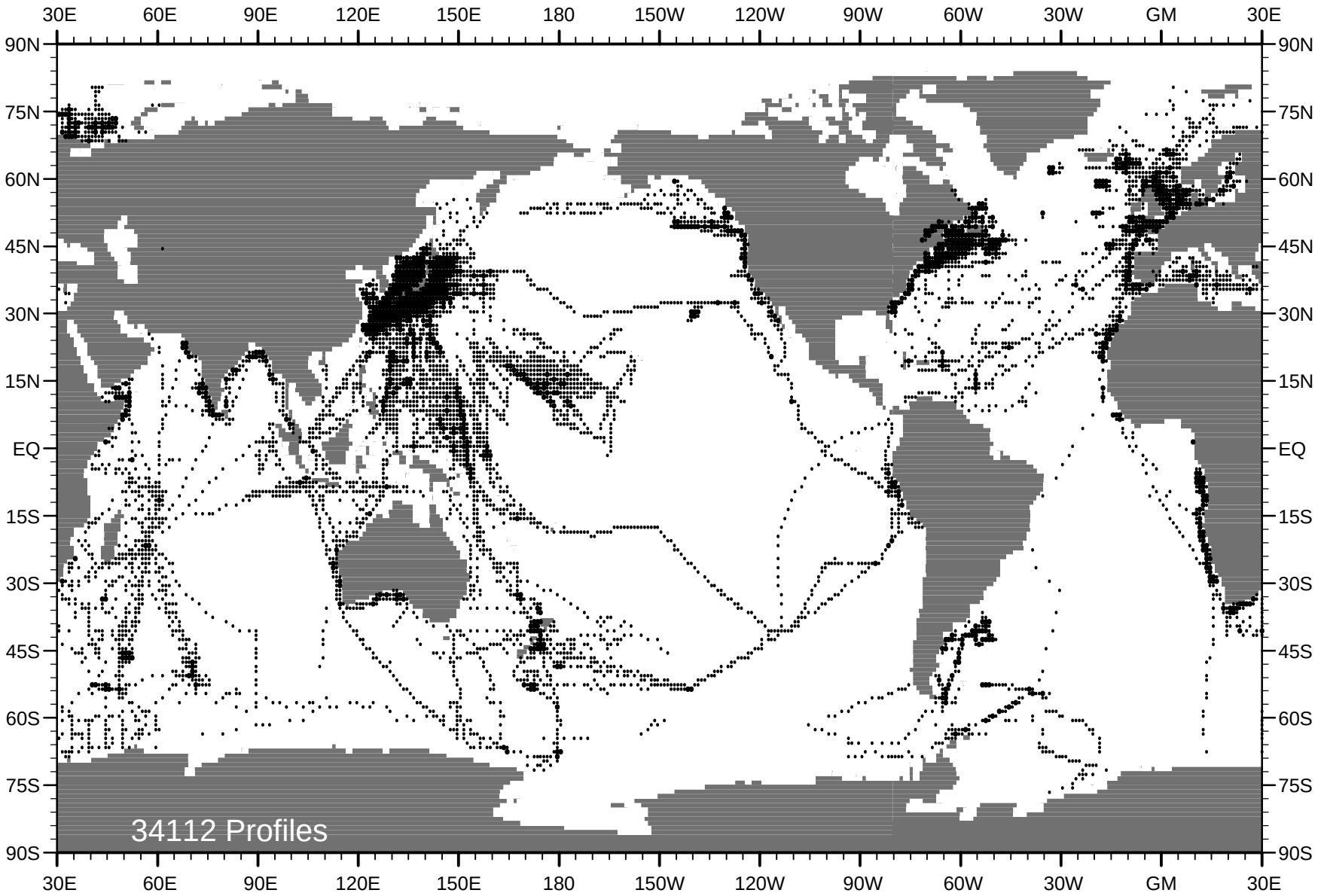

Fig. A33 WOD01 MBT profile distribution for year 1973 .

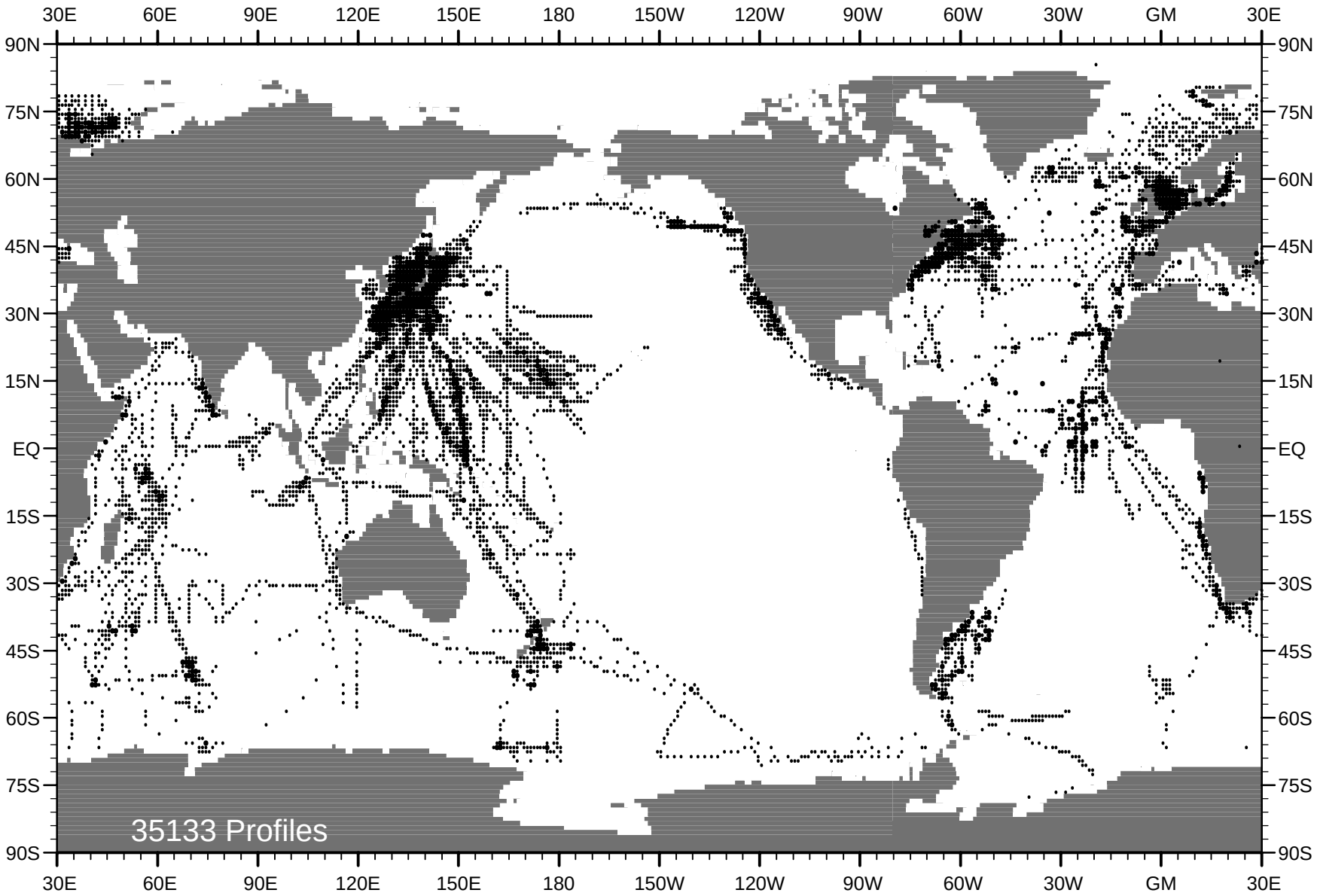

Fig. A34 WOD01 MBT profile distribution for year 1974 .

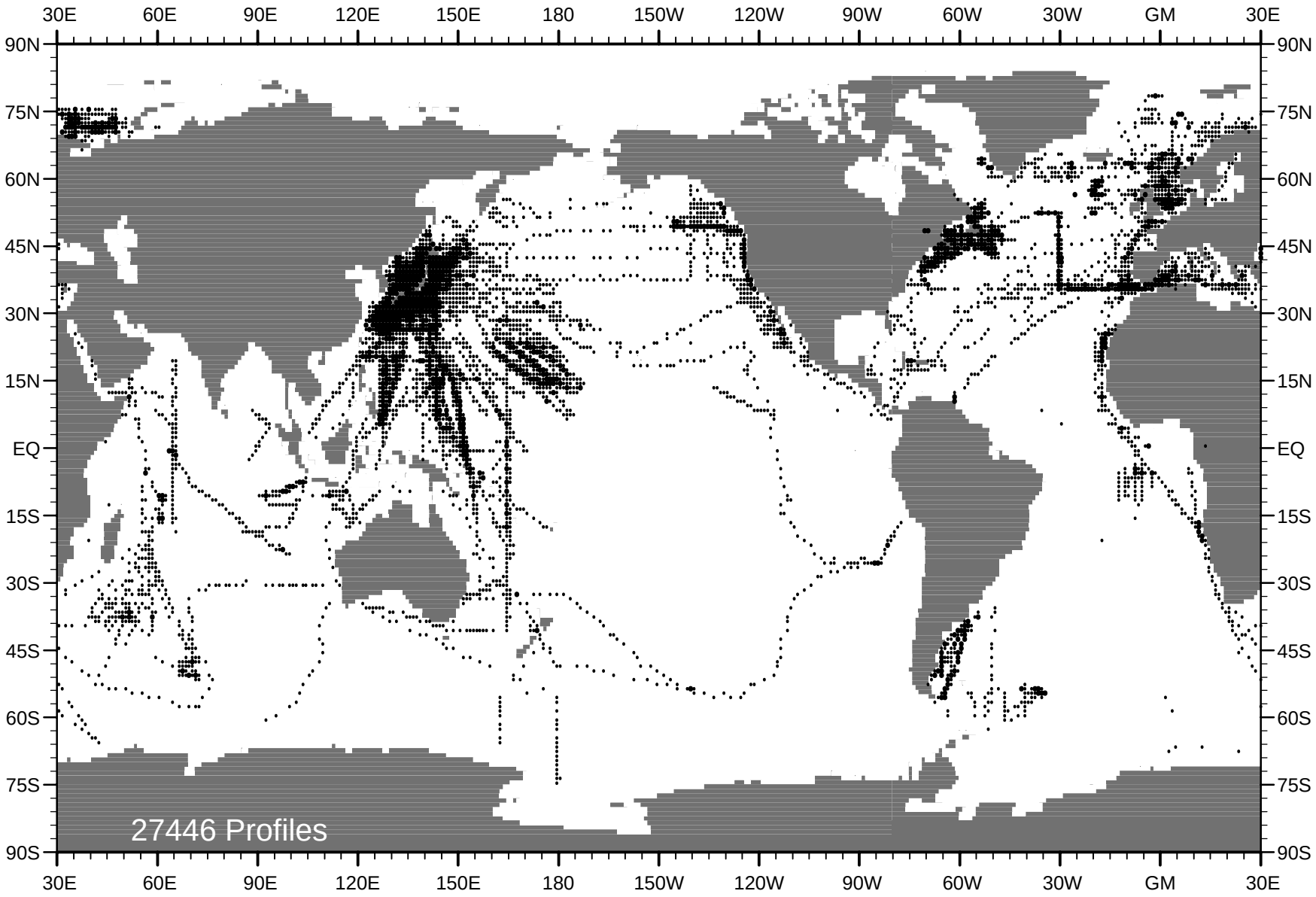

Fig. A35 WOD01 MBT profile distribution for year 1975 .

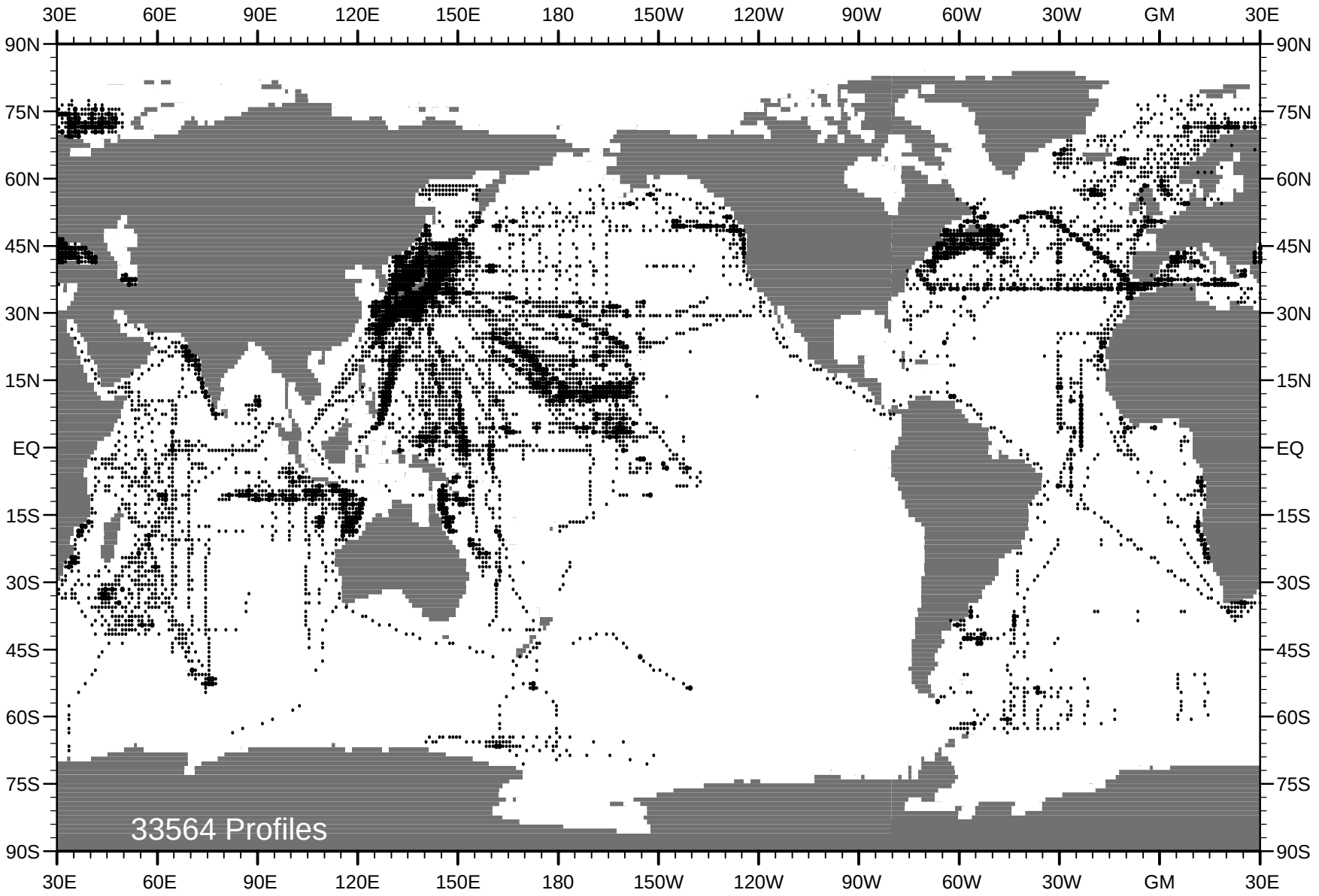

Fig. A36 WOD01 MBT profile distribution for year 1976 .

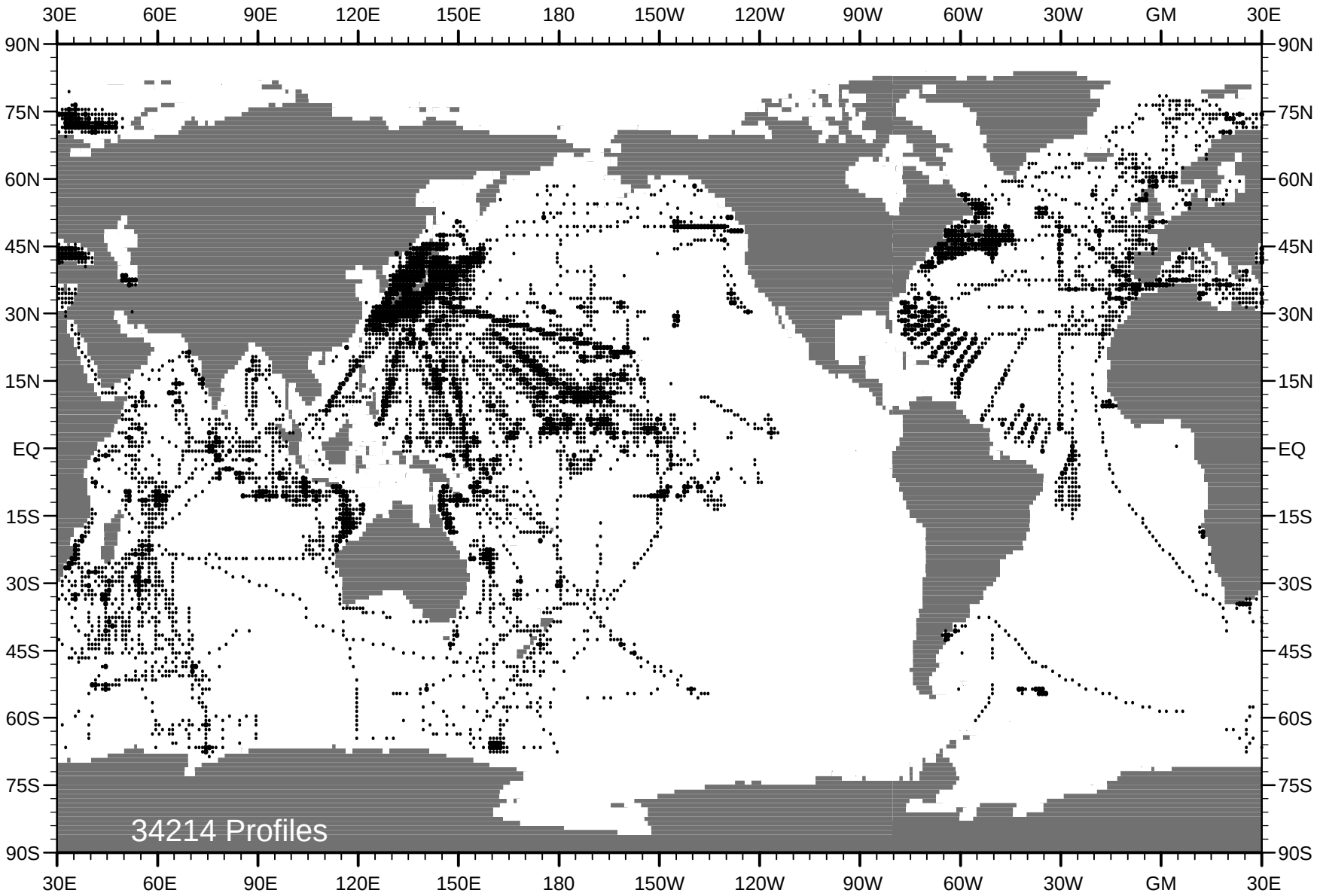

Fig. A37 WOD01 MBT profile distribution for year 1977 .

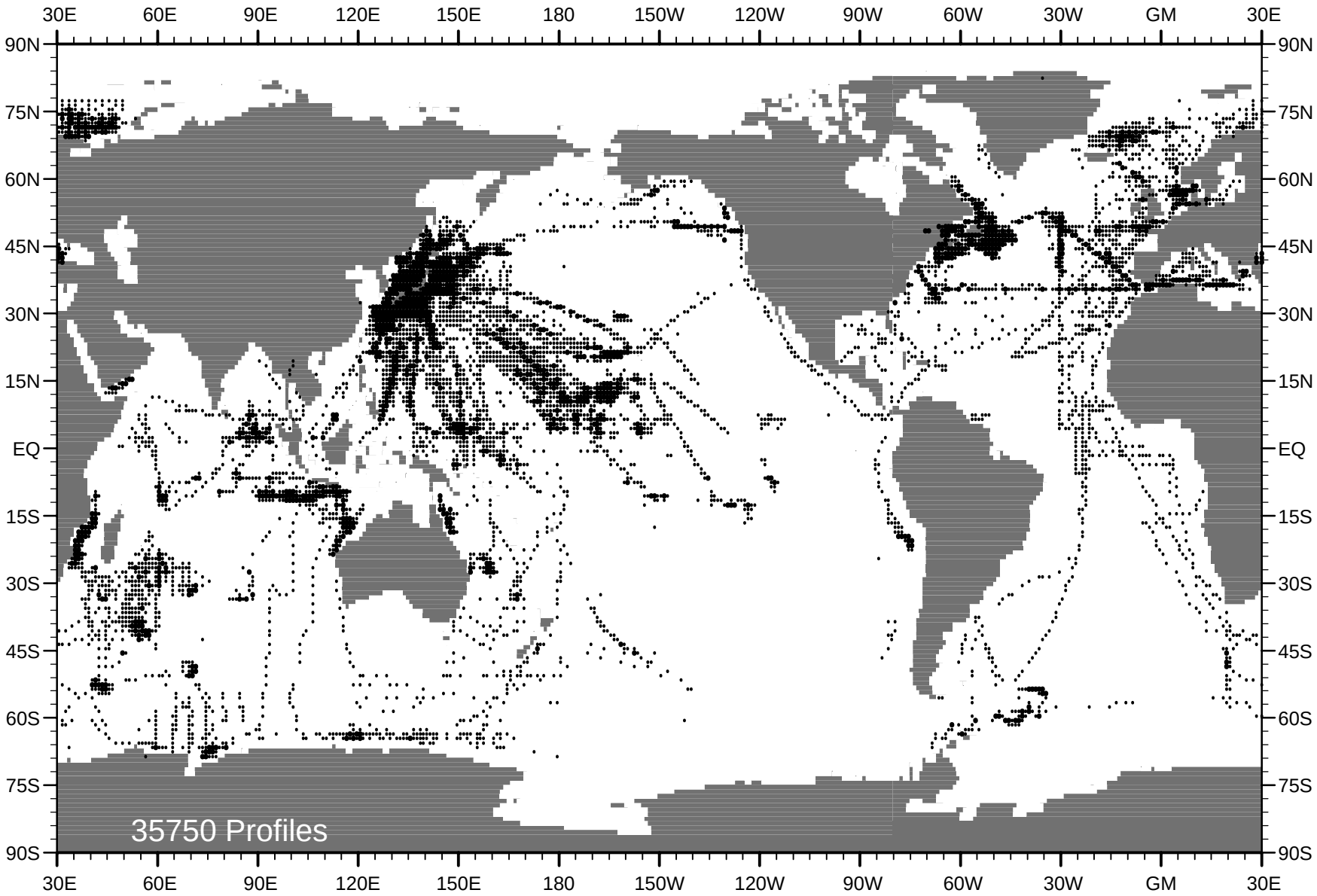

Fig. A38 WOD01 MBT profile distribution for year 1978 .

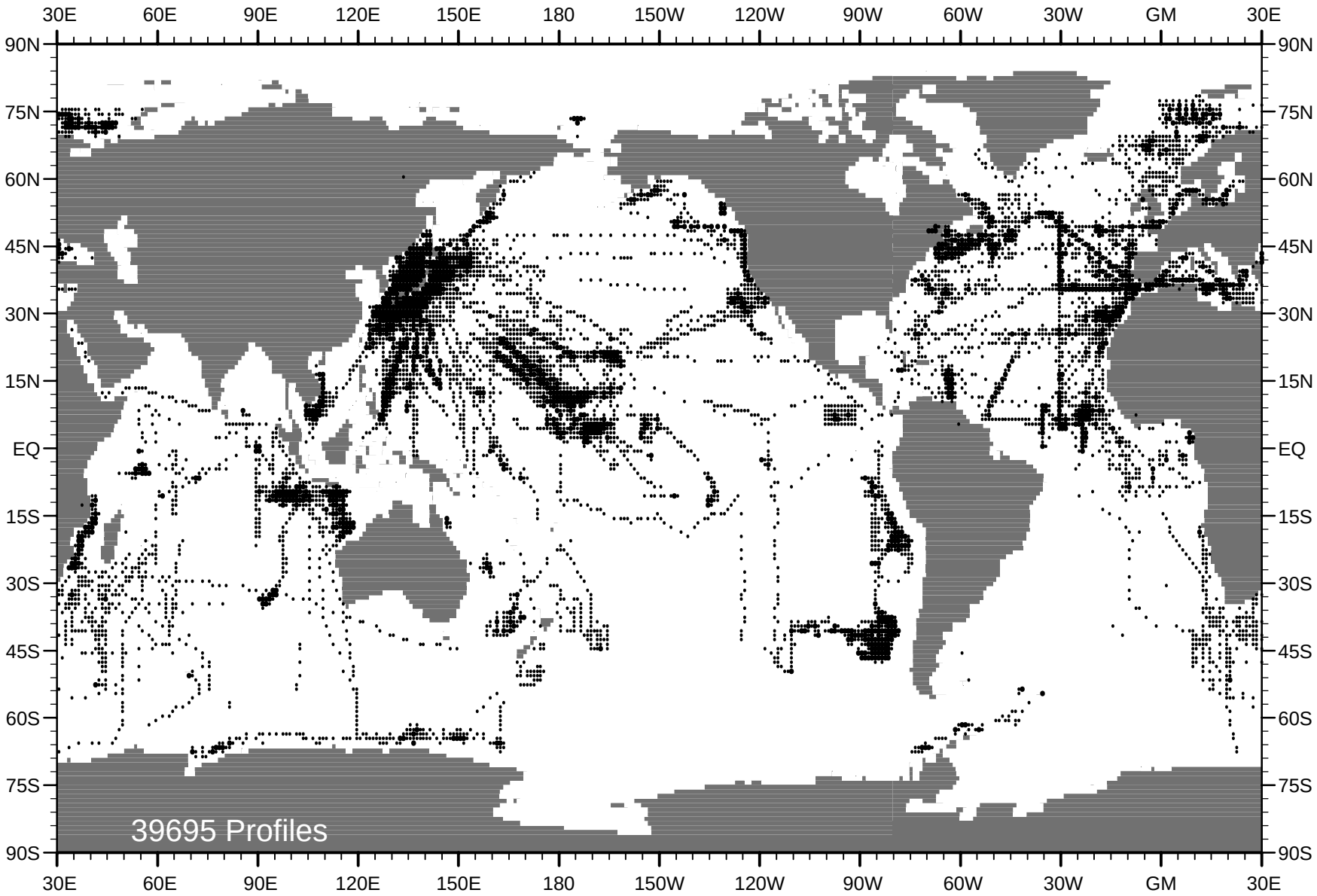

Fig. A39 WOD01 MBT profile distribution for year 1979 .

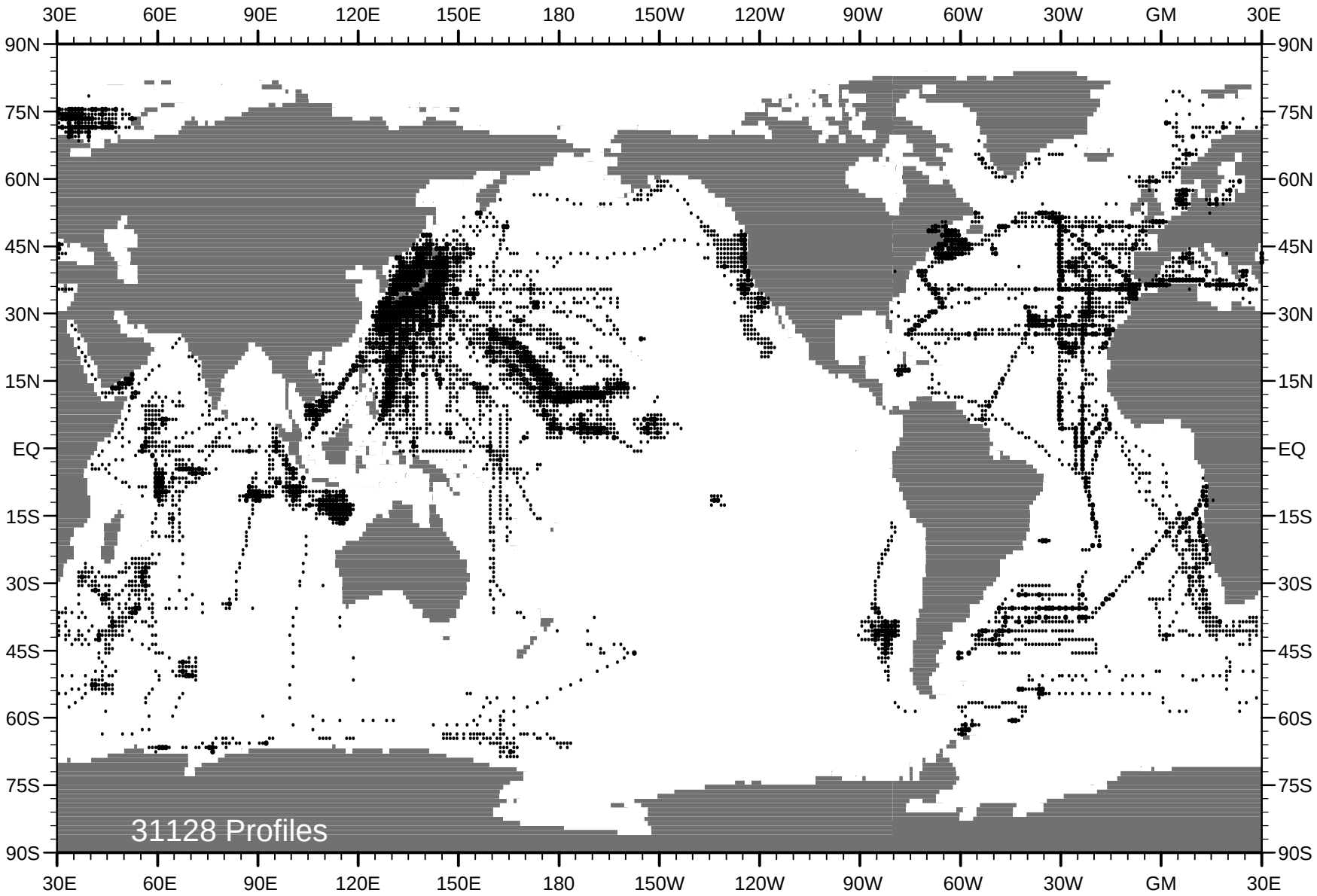

Fig. A40 WOD01 MBT profile distribution for year 1980 .

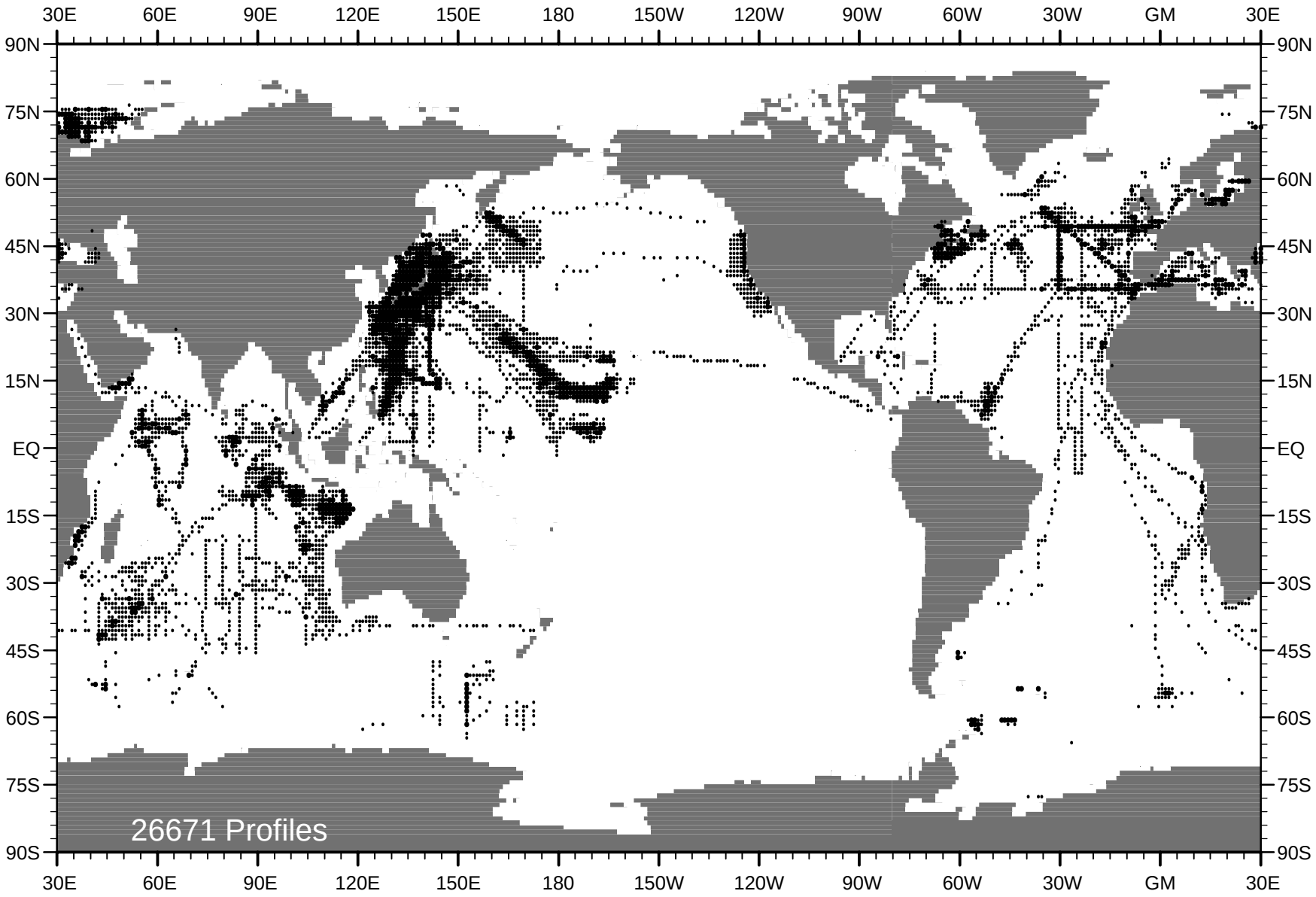

Fig. A41 WOD01 MBT profile distribution for year 1981 .

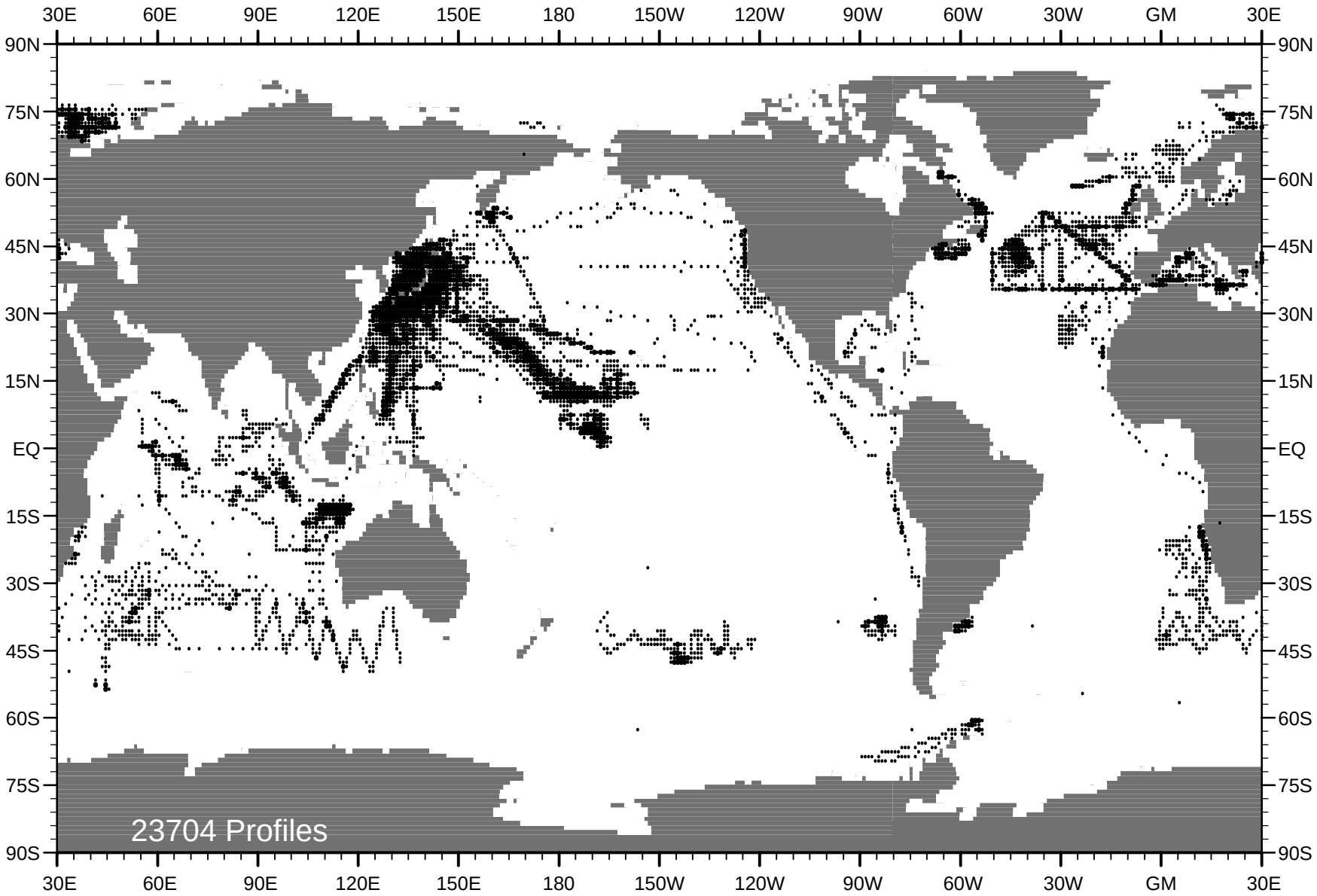

Fig. A42 WOD01 MBT profile distribution for year 1982 .

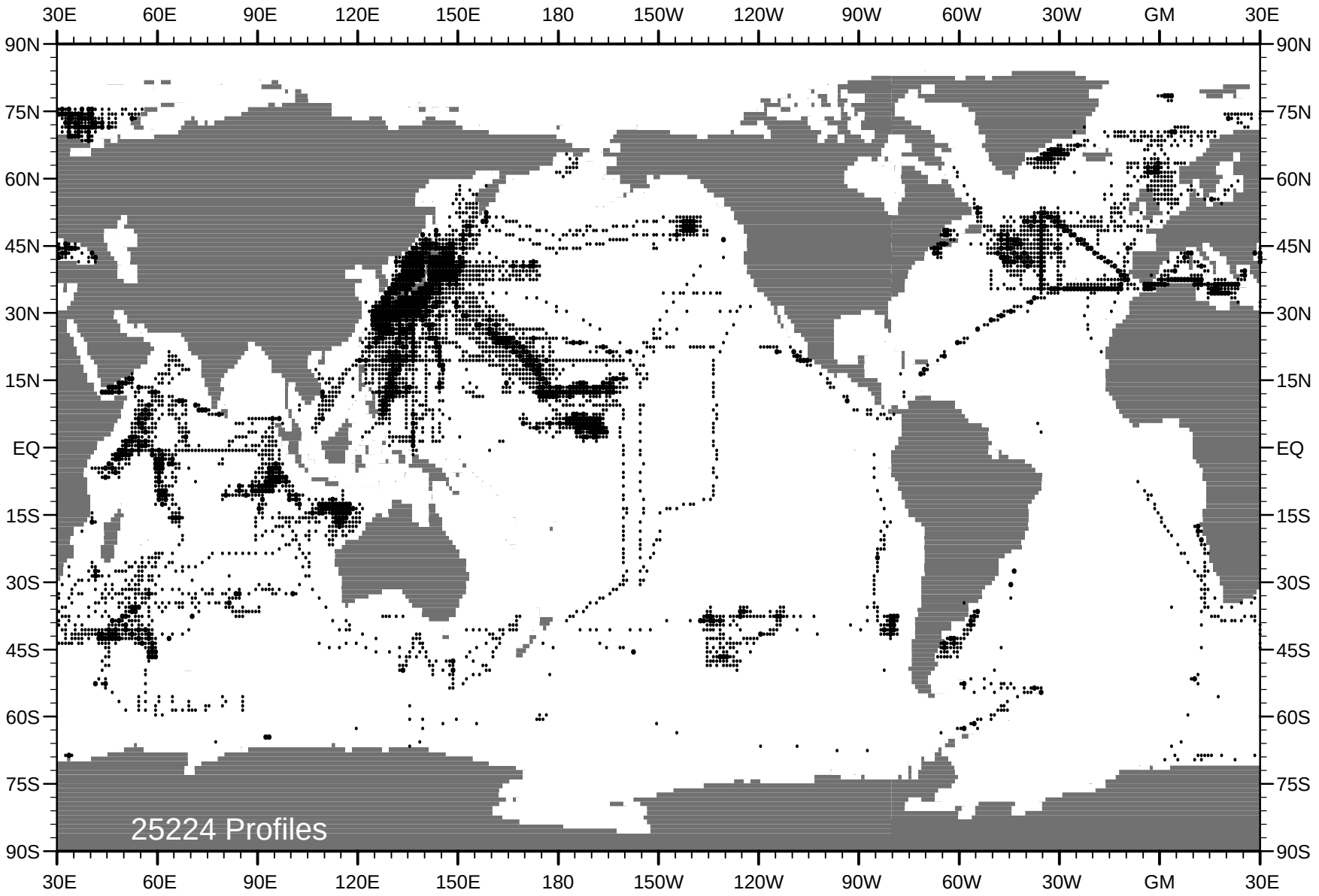

Fig. A43 WOD01 MBT profile distribution for year 1983 .

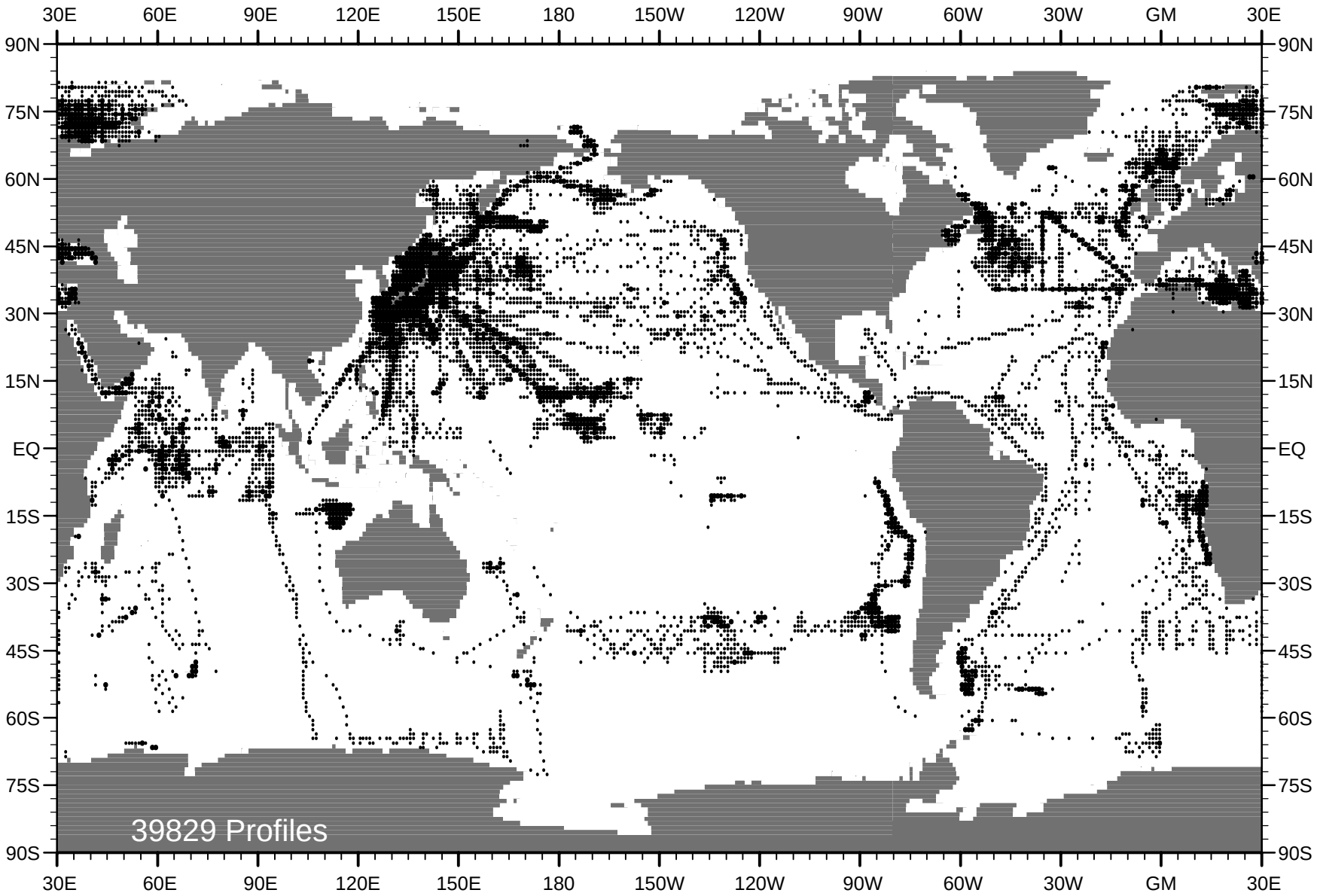

Fig. A44 WOD01 MBT profile distribution for year 1984 .

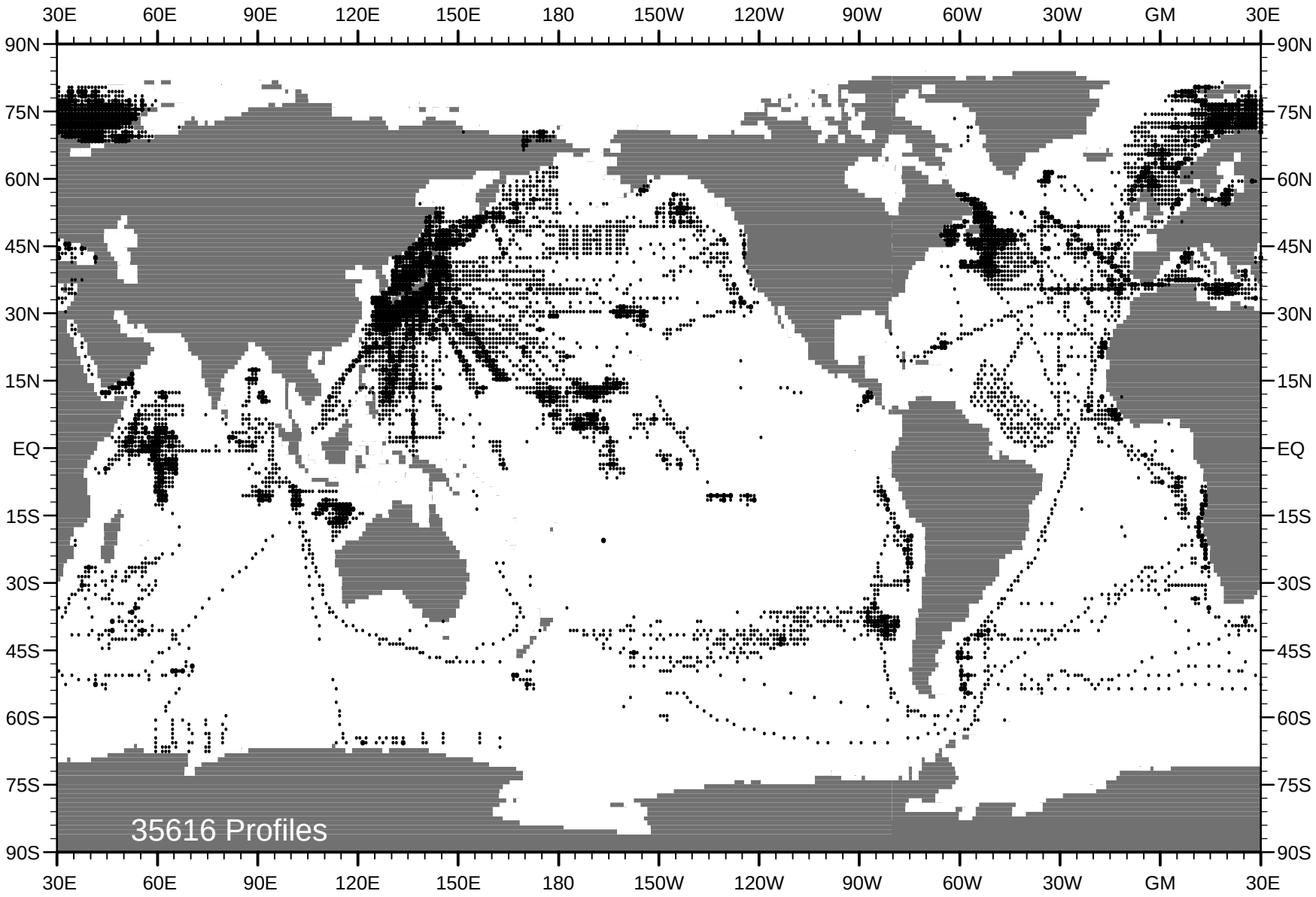

Fig. A45 WOD01 MBT profile distribution for year 1985 .

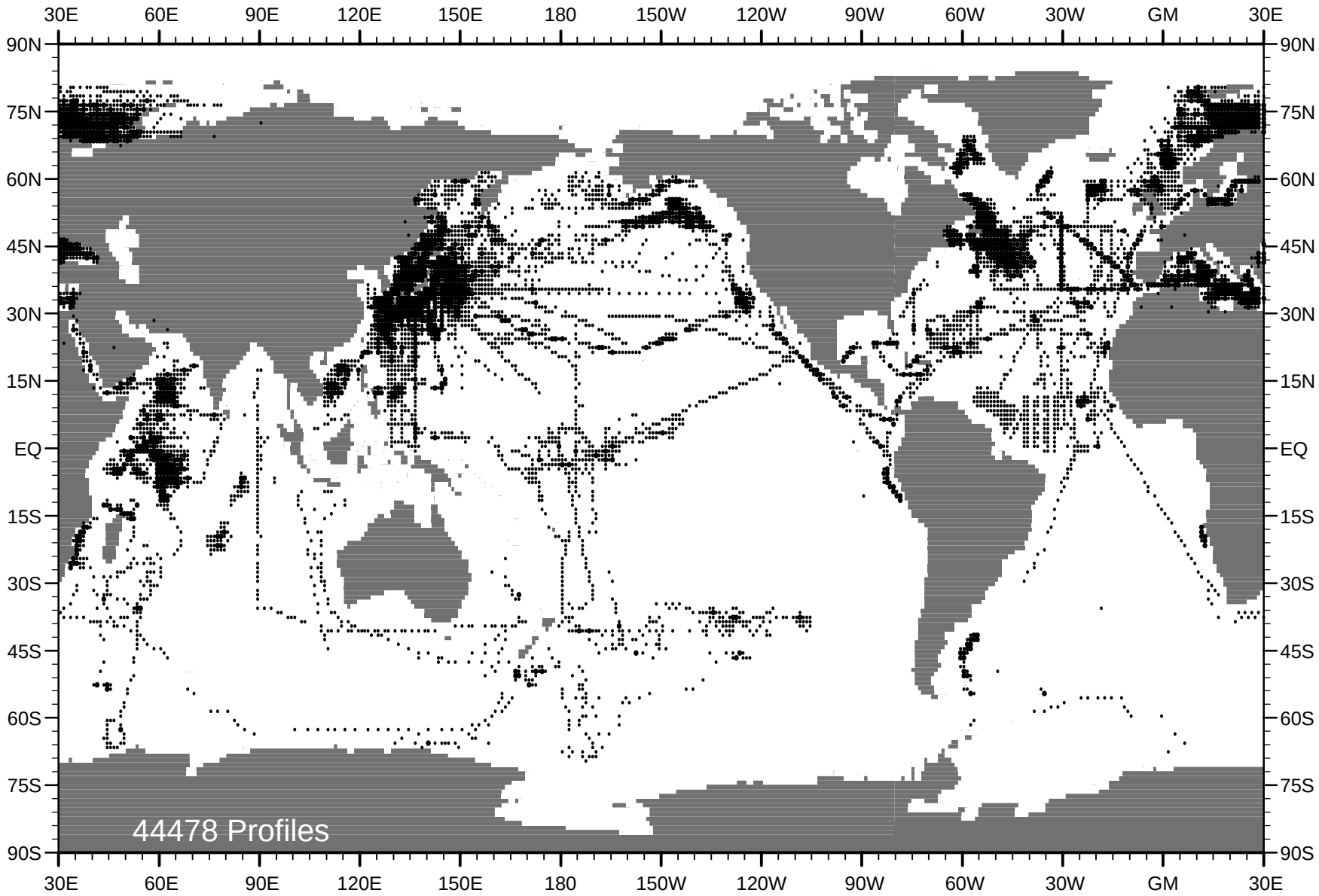

Fig. A46 WOD01 MBT profile distribution for year 1986 .

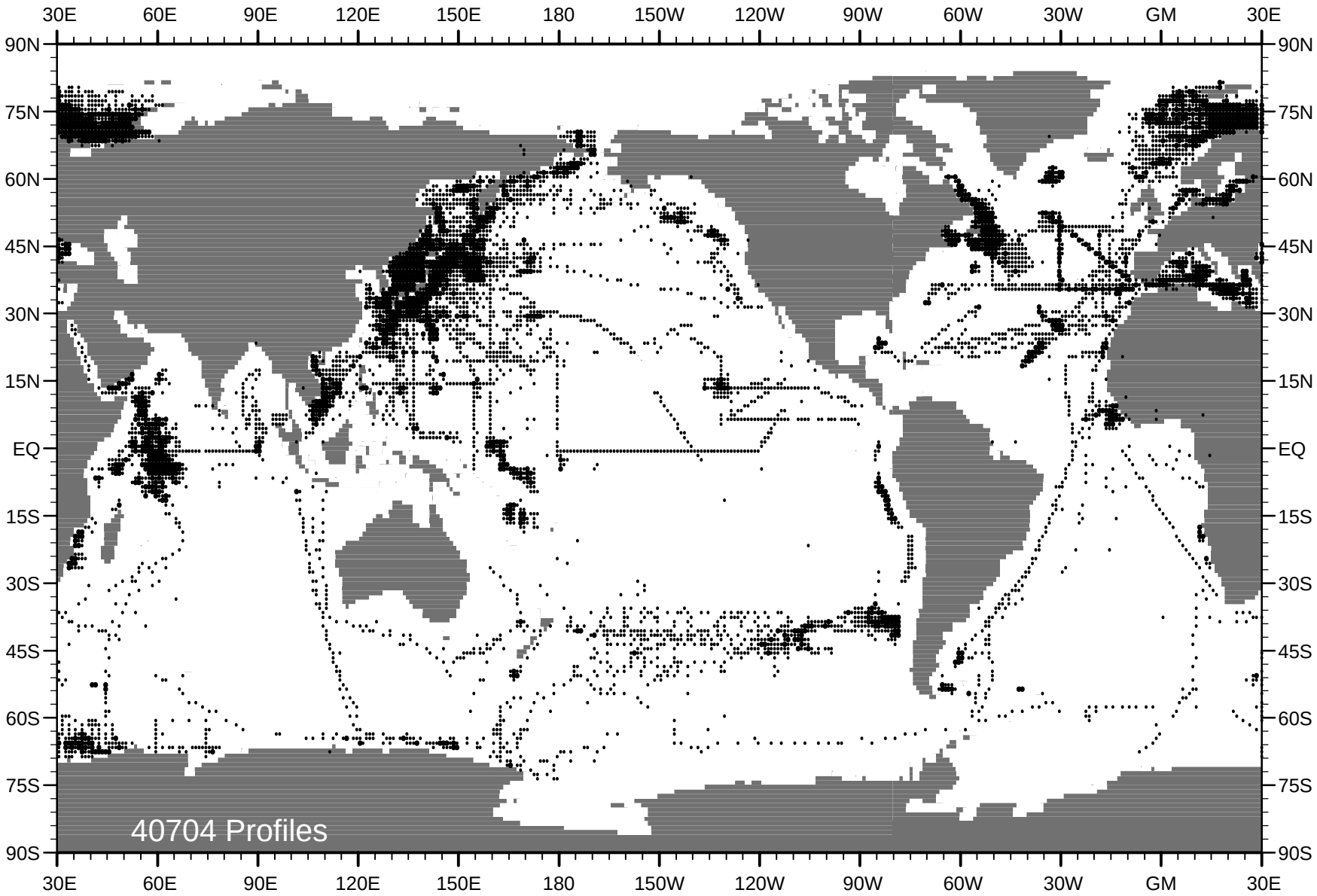

Fig. A47 WOD01 MBT profile distribution for year 1987 .

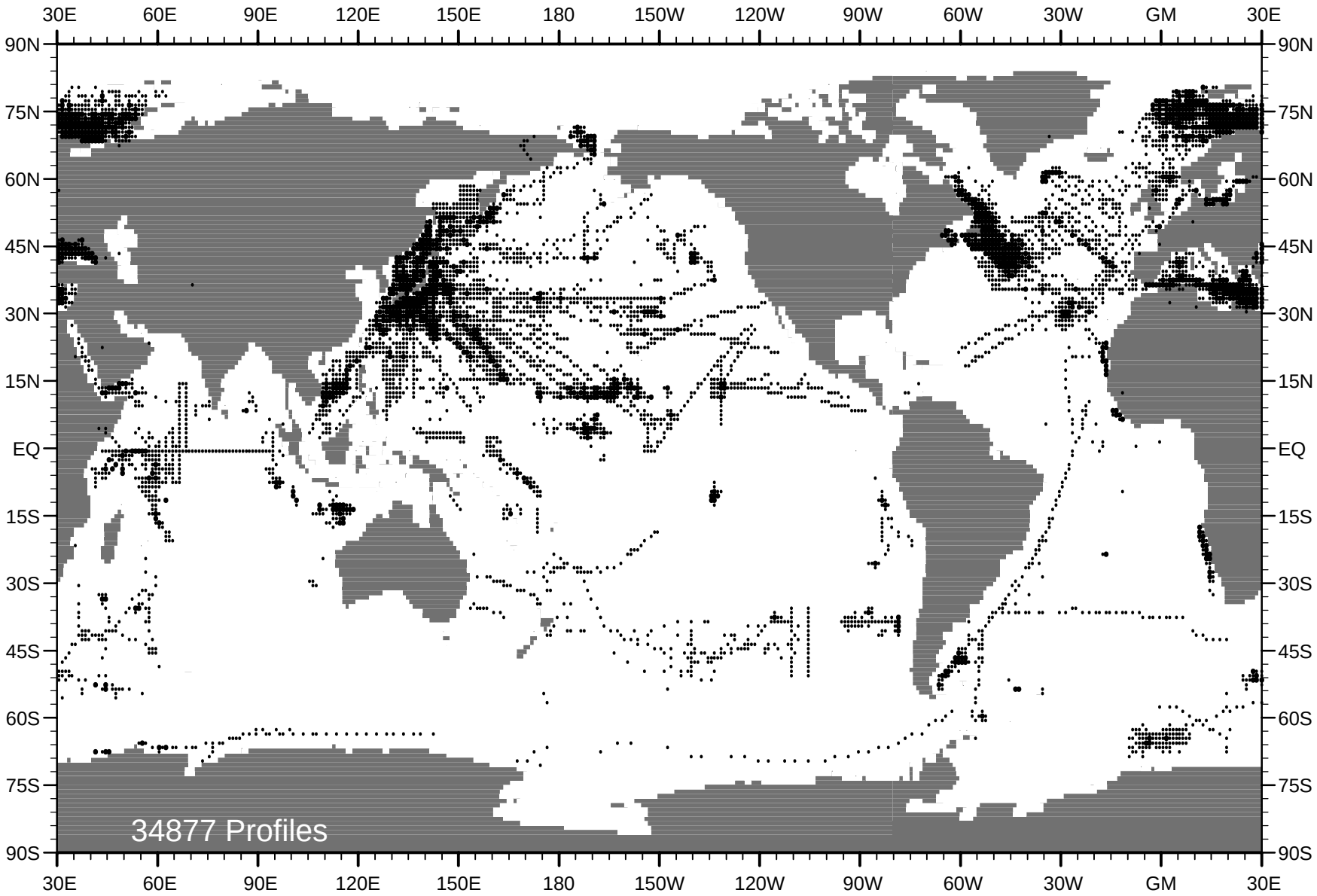

Fig. A48 WOD01 MBT profile distribution for year 1988 .

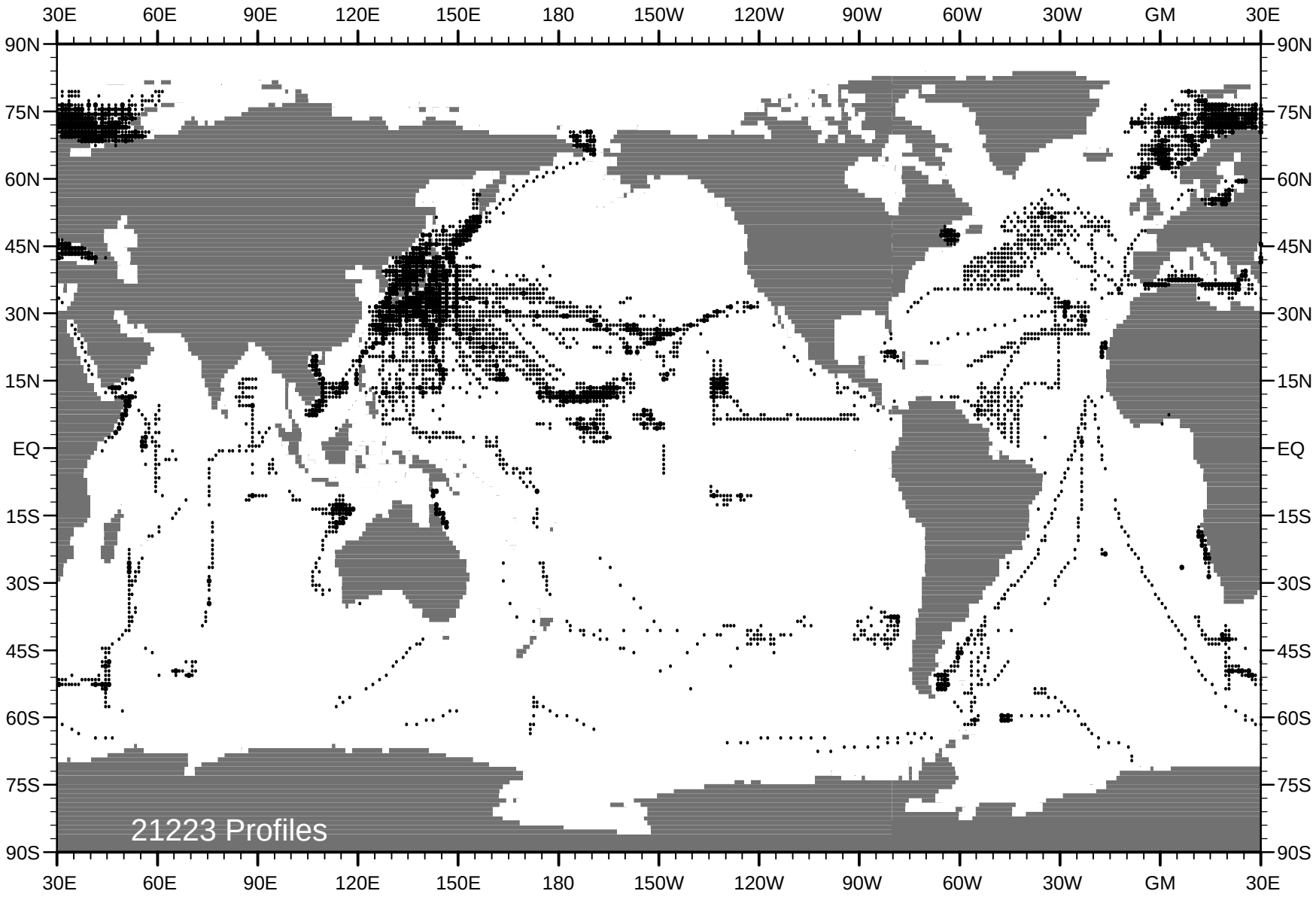

Fig. A49 WOD01 MBT profile distribution for year 1989 .

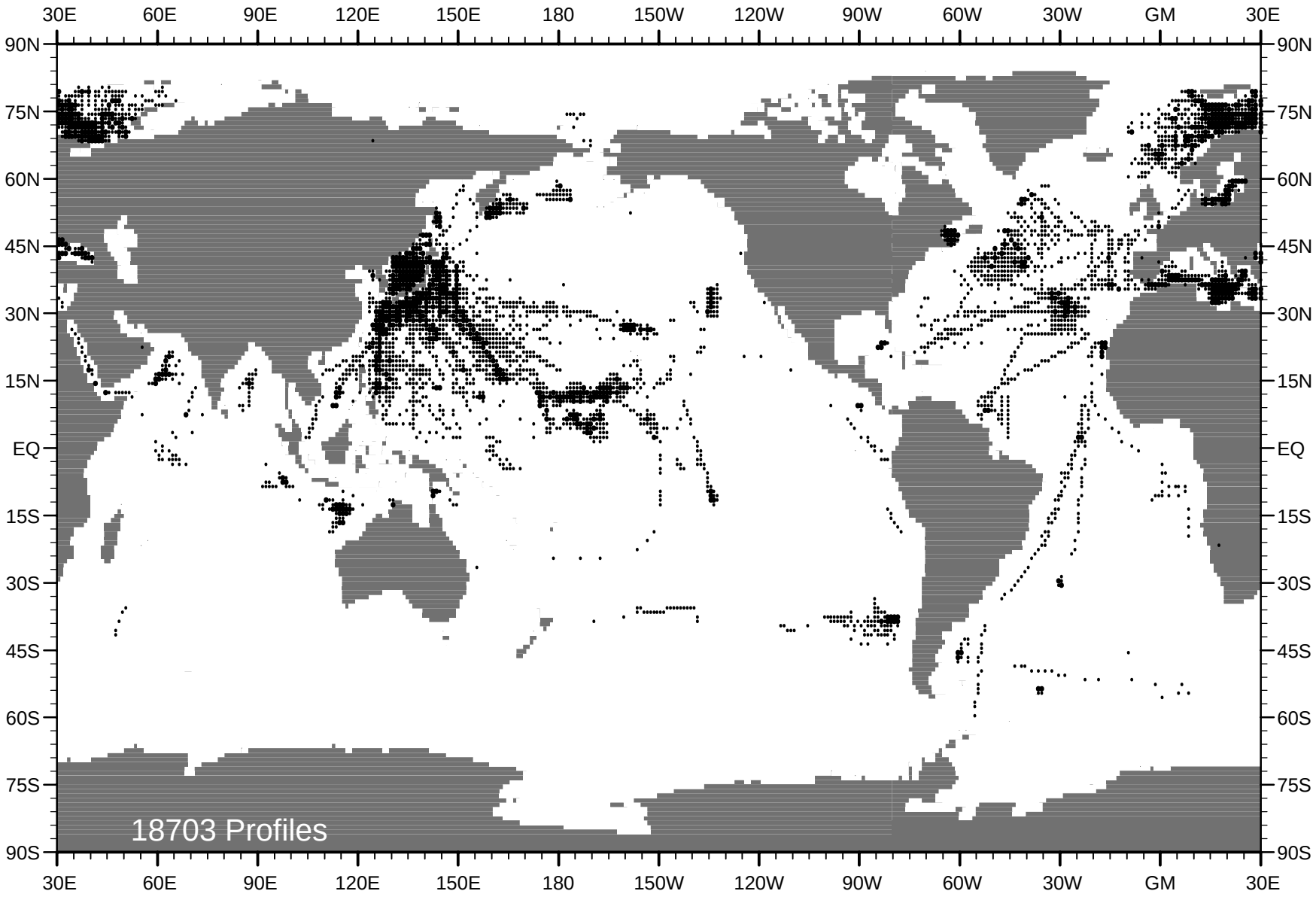

Fig. A50 WOD01 MBT profile distribution for year 1990 .

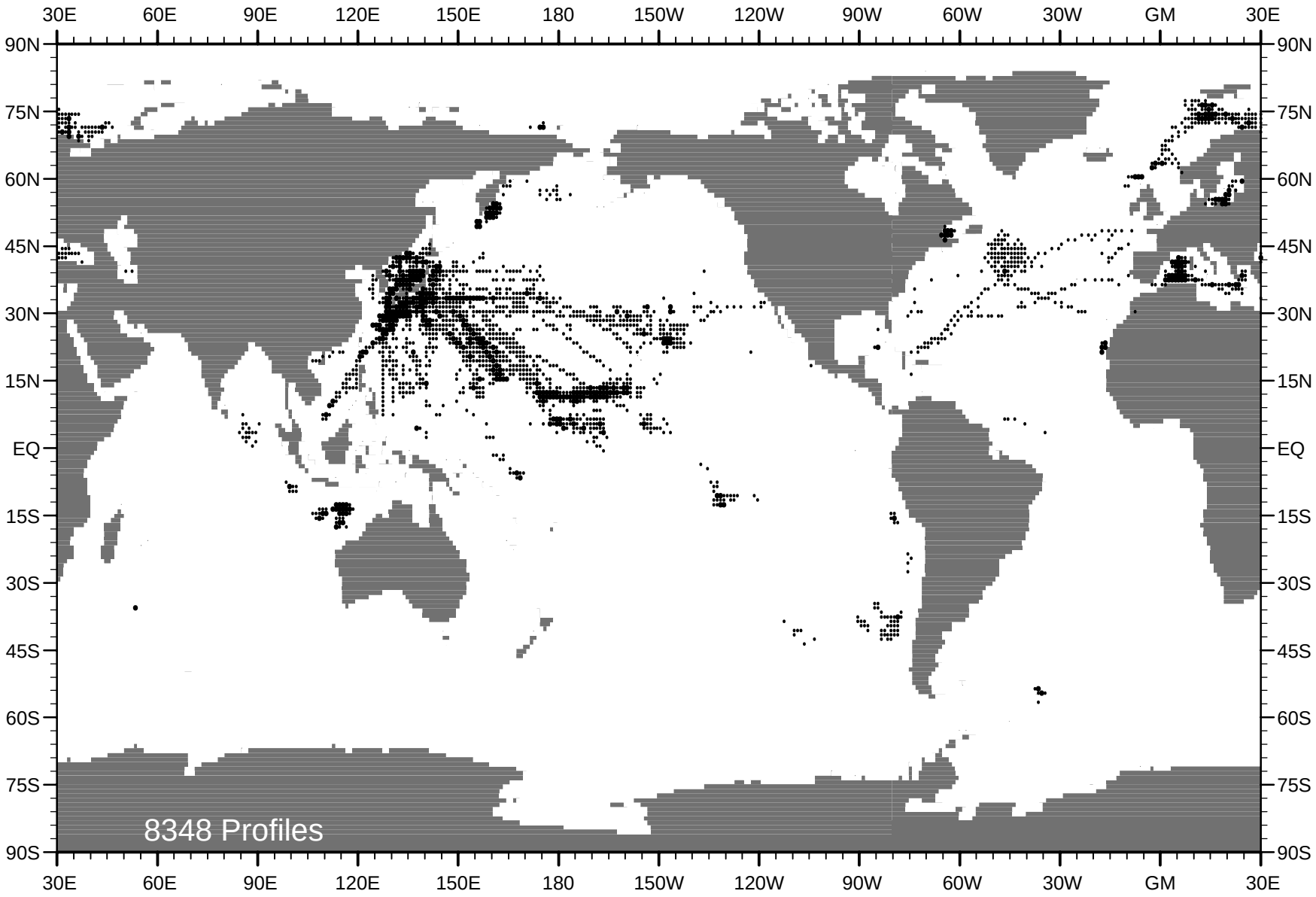

Fig. A51 WOD01 MBT profile distribution for year 1991 .

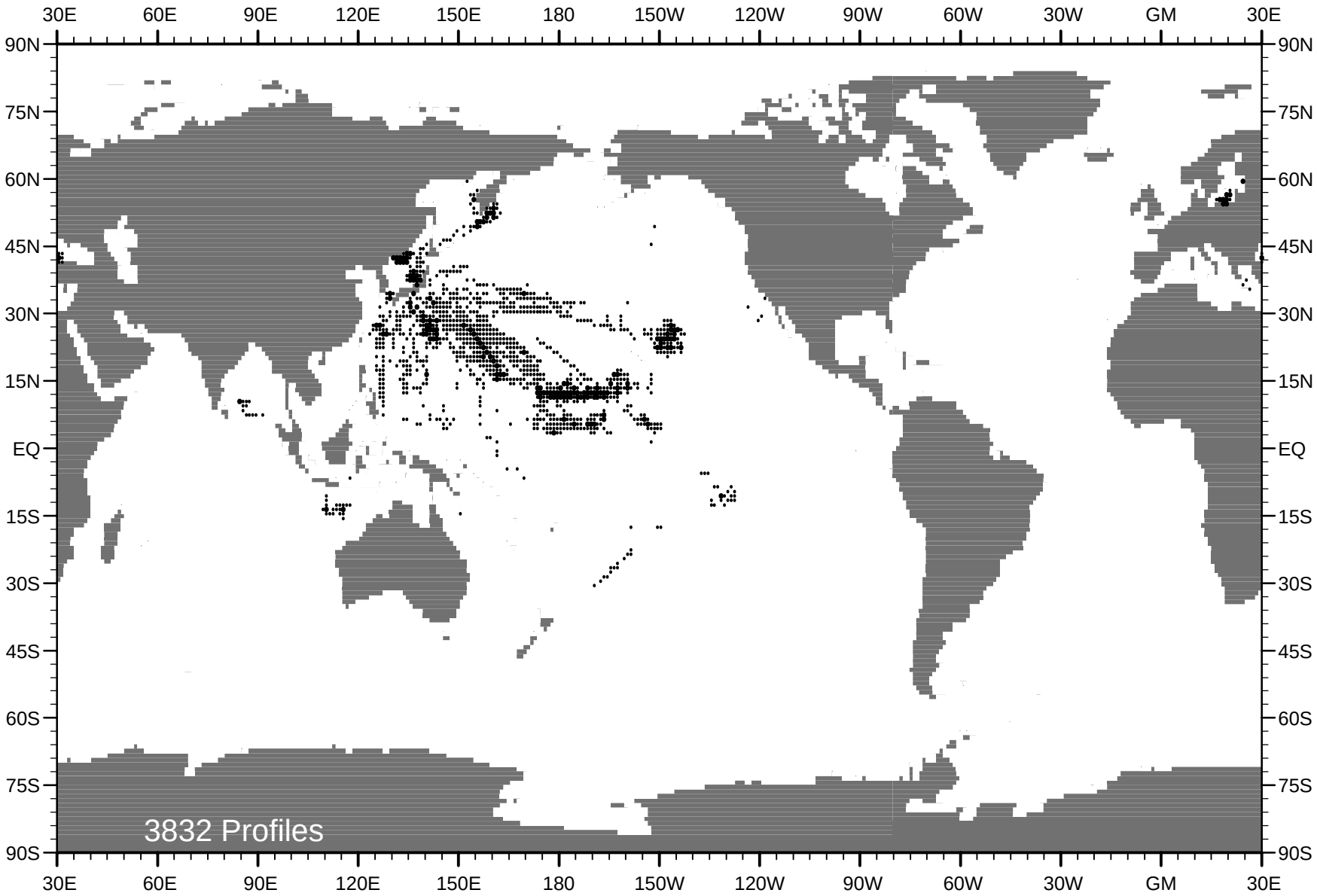

Fig. A52 WOD01 MBT profile distribution for year 1992 .

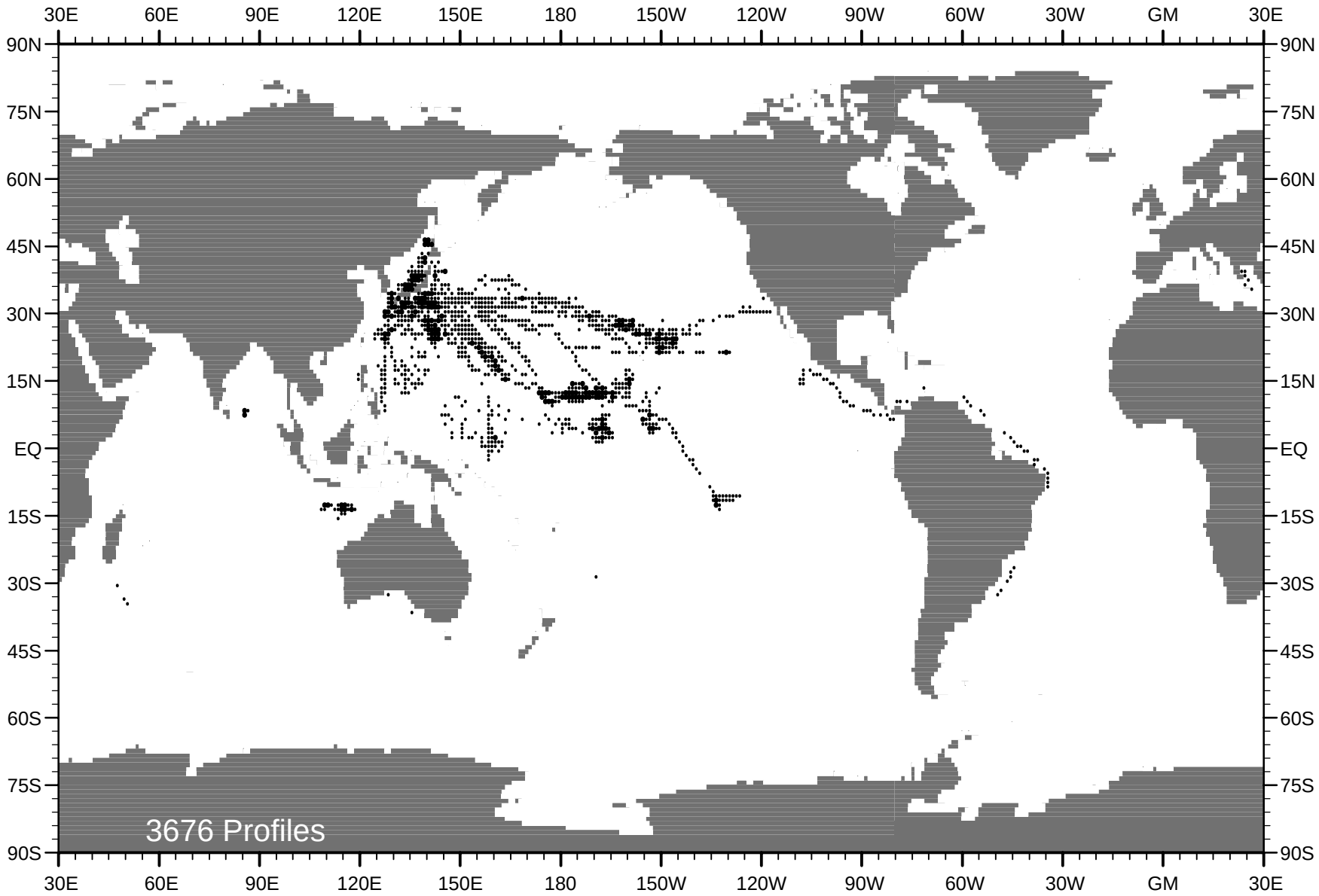

Fig. A53 WOD01 MBT profile distribution for year 1993 .

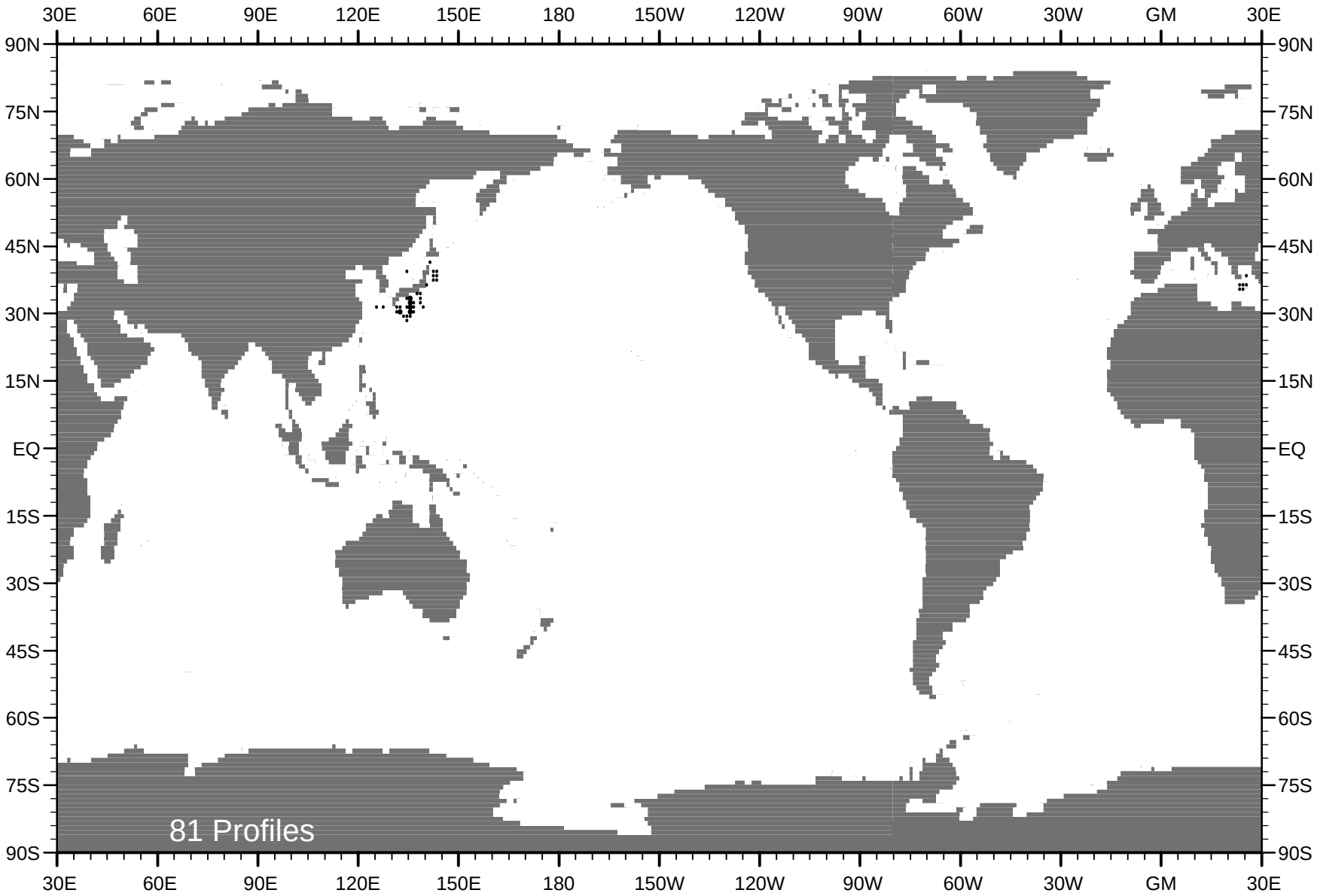

Fig. A54 WOD01 MBT profile distribution for year 1994 .

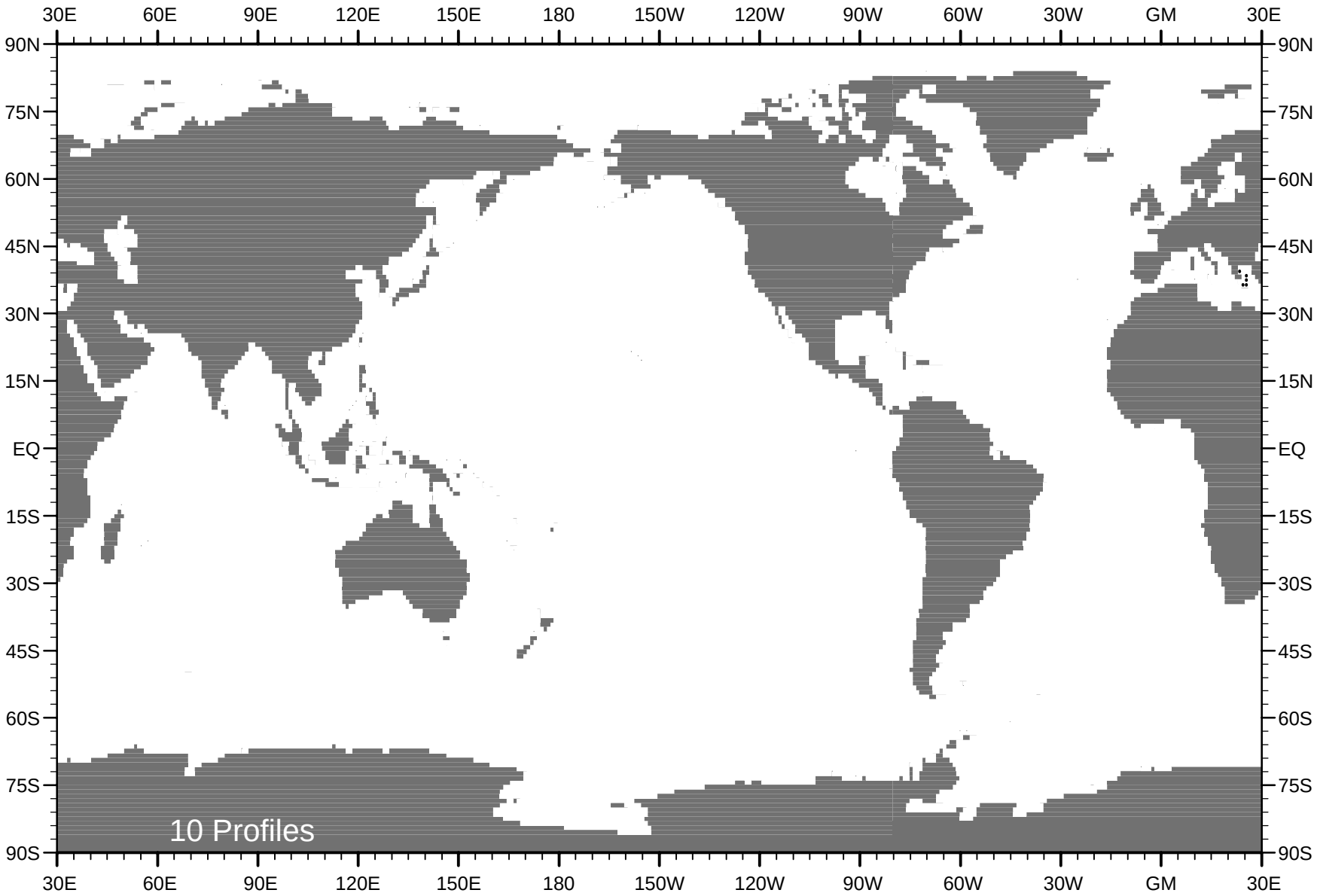

Fig. A55 WOD01 MBT profile distribution for year 1995 .

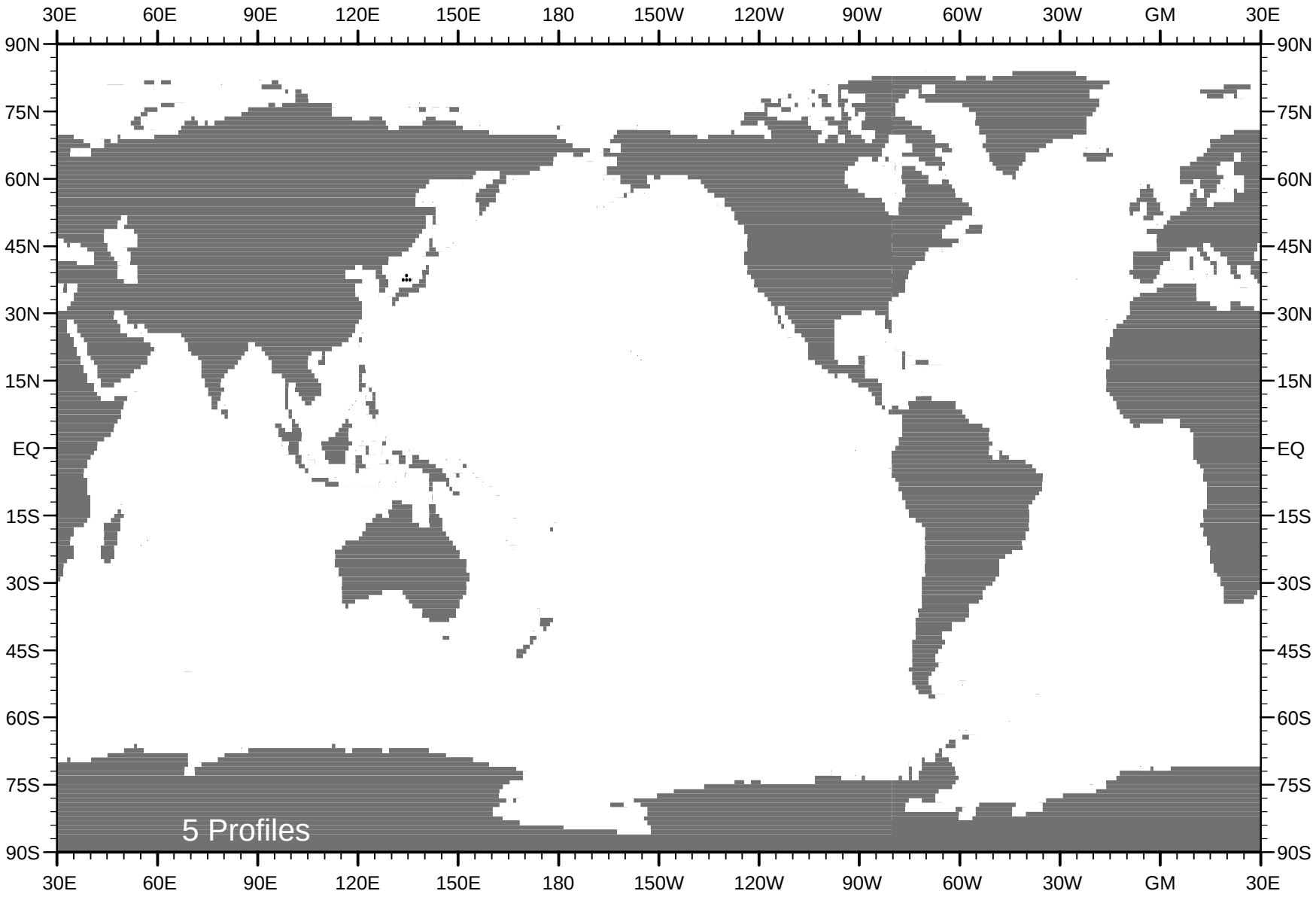

Fig. A56 WOD01 MBT profile distribution for year 1999 .

Chapter 2: Temporal Distribution of Expendable Bathythermograph Profiles

1. INTRODUCTION

The Expendable Bathythermograph (XBT) was deployed beginning in 1966 and has replaced the MBT in many measurement programs. There are different models of XBT instruments which have different maximum depth penetration and/or other different characteristics. The T-4, T-6, and T-7 probes reach maximum depths of 450, 750, and 750 m respectively. The T-7 probe differs from the T-6 probe in that it can be dropped from a faster moving ship and still maintain certain accuracy standards. The T-5 probe reaches a maximum depth of about 1800 m.

The depth of a temperature measurement from an XBT instrument is determined using the time elapsed between when the probe enters the water and the time each temperature measurement is made. A vendor supplied drop-rate equation is utilized. However, the vendor supplied drop-rate equation for T-4, T-6, and T-7 probes was found to have a systematic error and a new equation has been developed by the international research community (Hanawa *et al.*, 1995; UNESCO, 1994). The recommended practice regarding exchange and archiving of XBT profiles is that XBT profile data be exchanged or sent to data centers without correction for the systematic depth error, until an "international mechanism is established to implement the general use of the new equation" (UNESCO, 1994). This policy is to avoid double corrections.

2. The XBT drop rate error

The XBT instrument does not measure pressure or depth directly. Depth of the instrument is computed from the elapsed time from when the probe enters the water through use of a drop-rate equation. There are several models of the Sippican Expendable Bathythermograph instrument. The manufacturer's drop rate equation for the T4, T-6, and T-7 models are known to contain a systematic error. To correct for this error a new drop rate equation has been computed (Hanawa *et al.*, 1995; UNESCO, 1994). By international agreement (UNESCO, 1994), XBT profile depths are supposed to be reported and archived using depths computed from the "old" drop-rate equation. This policy is to avoid possible confusion as to whether the profiles have been converted or not so as to avoid double conversion. NODC/WDC archives the XBT data as submitted. **The observed level XBT profiles are the same data as submitted by originators. However, in preparing standard level data for WOD98, the NODC/OCL corrected the depths of the originator's XBT profiles using the new drop-rate equation before interpolating to standard levels.**

3. XBT PROFILE DISTRIBUTIONS

Figure 1 shows the number of XBT profiles contained in WOD01 for the World Ocean as a function of year. Figures 2 and 3 show the time series for the northern and southern hemispheres respectively. There are a total of 1,743,592 XBT profiles for the entire World Ocean with 312,290 profiles (17.9%) measured in the southern hemisphere and 1,431,300 profiles (82.1%) measured in the northern hemisphere. Table 1 provides the exact number of XBT profiles included in WOD01 as a function of year. The geographic distribution of XBT profiles for individual years for 1966-2001 are shown in Figures B1-B36. Most profiles have been made in the northern hemisphere, but the southern hemisphere coverage has been increased due to international data archaeology and rescue efforts and the World Ocean Database project (Levitus *et al.* 1994, 2002).

Table 6 National contributions of (XBT) profiles sorted by percent contribution of each country.

NODC Country Code	Country Name	XBT Count	% of Total
31	UNITED STATES	548779	31.47
32	UNITED STATES	248328	14.24
49	JAPAN	236424	13.56
74	UNITED KINGDOM	164948	9.46
99	UNKNOWN	96321	5.52
9	AUSTRALIA	83155	4.77
6	GERMANY, FEDERAL REPUBLIC OF	56544	3.24
18	CANADA	48664	2.79
35	FRANCE	45690	2.62
54	LIBERIA	33290	1.91
PA	PANAMA	32697	1.88
64	NETHERLANDS	15294	0.88
90	RUSSIA	14578	0.84
SI	SINGAPORE	14565	0.84
BH	BAHAMAS	9713	0.56
33	UNITED STATES	8874	0.51
AG	ANTIGUA	6975	0.40
58	NORWAY	6908	0.40
91	SOUTH AFRICA	5890	0.34
26	DENMARK	5724	0.33
SV	SAINT VINCENT	5598	0.32
61	NEW ZEALAND	5587	0.32
76	CHINA, THE PEOPLES REPUBLIC OF	4568	0.26
77	SWEDEN	4552	0.26
46	ICELAND	4348	0.25
HK	HONG KONG	3210	0.18
29	SPAIN	2995	0.17
BA	BARBADOS	2601	0.15
20	CHILE	2438	0.14
TN	TONGA	2328	0.13
66	PHILIPPINES	2298	0.13
CY	CYPRUS	2258	0.13
57	MEXICO	2234	0.13
8	ARGENTINA	2184	0.13
KU	KUWAIT	1812	0.10
67	POLAND	1320	0.08
42	INDONESIA	1214	0.07
FJ	FIJI ISLANDS	866	0.05
48	ITALY	772	0.04
68	PORTUGAL	732	0.04
65	PERU	714	0.04
28	ECUADOR	492	0.03
ML	MALTA	431	0.02
41	INDIA	362	0.02
14	BRAZIL	218	0.01
SA	SAUDI ARABIA	197	0.01

ZZ	MISCELLANEOUS ORGANIZATIONAL UNITS	195	0.01
95	YUGOSLAVIA	173	0.01
92	URUGUAY	146	0.01
MA	MAURITIUS	77	0.00
7	GERMANY, DEMOCRATIC REPUBLIC OF	67	0.00
55	MALAGASY REPUBLIC	62	0.00
24	KOREA, REPUBLIC OF	53	0.00
IC	IVORY COAST	43	0.00
UR	UKRAINE	33	0.00
22	COLOMBIA	32	0.00
86	THAILAND	29	0.00
CR	COSTA RICA	29	0.00
HO	HONDURAS	12	0.00
SC	SEYCHELLES	11	0.00
TT	TRINIDAD/TOBAGO	6	0.00
21	TAIWAN	3	0.00
RU	RUSSIA	1	0.00

The United States, Russia, and Japan have multiple country codes. This is because the NODC Institution Code is limited to two digits and these countries each have more than 99 institutions that can potentially transfer data to NODC/WDC.

Table 7 The number of all XBT profiles in WOD01 as a function of year for the World Ocean.

Total Number of Profiles = 1,743,592

YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE
1966	1747	1975	54097	1984	54051	1993	61257
1967	9390	1976	48268	1985	67258	1994	52811
1968	26671	1977	54178	1986	72955	1995	62882
1969	34319	1978	52748	1987	69950	1996	48438
1970	44411	1979	52666	1988	59651	1997	41810
1971	57605	1980	52063	1989	42175	1998	34432
1972	53139	1981	50879	1990	76186	1998	36449
1973	54918	1982	53253	1991	63763	2000	23988
1974	54850	1983	53464	1992	57551	2001	9319

Table 8 The number of all XBT profiles in WOD01 as a function of year for the southern hemisphere.

Total Number of Profiles = 312,290

YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE
1966	168	1975	4304	1984	8718	1993	17135
1967	644	1976	5912	1985	10193	1994	17102
1968	2136	1977	4778	1986	11400	1995	17730
1969	2032	1978	5800	1987	13050	1996	14532
1970	2561	1979	7161	1988	9875	1997	15779
1971	5163	1980	6680	1989	8698	1998	12132
1972	6548	1981	5717	1990	14803	1998	9864
1973	6424	1982	9395	1991	14204	2000	7816
1974	5898	1983	10203	1992	14242	2001	3493

Table 9 The number of all XBT profiles in WOD01 as a function of year for the northern hemisphere.

Total Number of Profiles = 1,431,300

YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE	YEAR	PROFILE
1966	1579	1975	49793	1984	45333	1993	44122
1967	8746	1976	42355	1985	57065	1994	35709
1968	24535	1977	49400	1986	61555	1995	45152
1969	32287	1978	46948	1987	56900	1996	33906
1970	41850	1979	45505	1988	49776	1997	26031
1971	52442	1980	45383	1989	33477	1998	22299
1972	46591	1981	45162	1990	61383	1998	26585
1973	48494	1982	43858	1991	49559	2000	16172
1974	48952	1983	43261	1992	43309	2001	5826

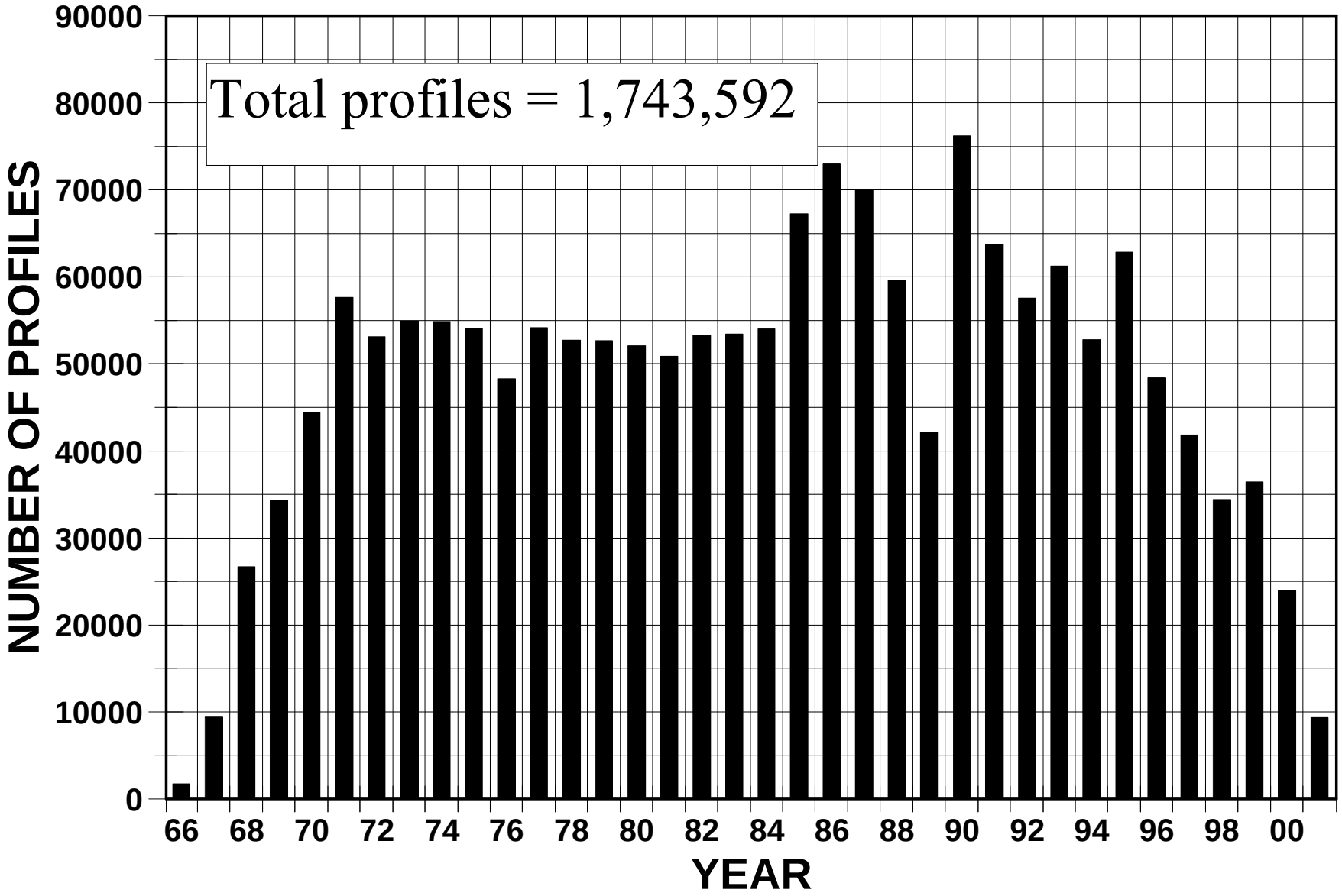

Fig. 5 Time series of XBT profiles in WOD01 for the world ocean as a function of year.

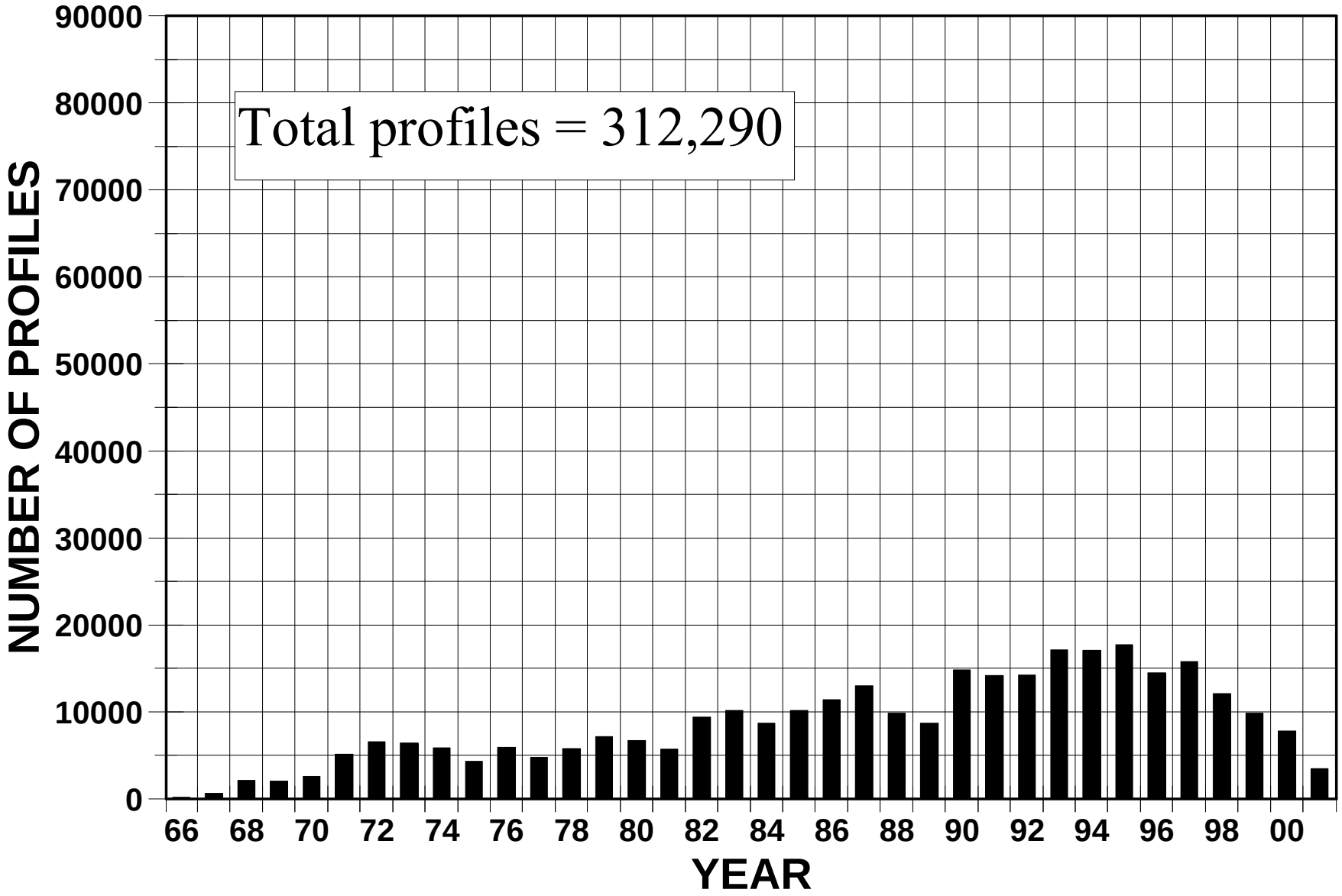

Fig. 6 Time series of XBT profiles in WOD01 for the southern hemisphere as a function of year.

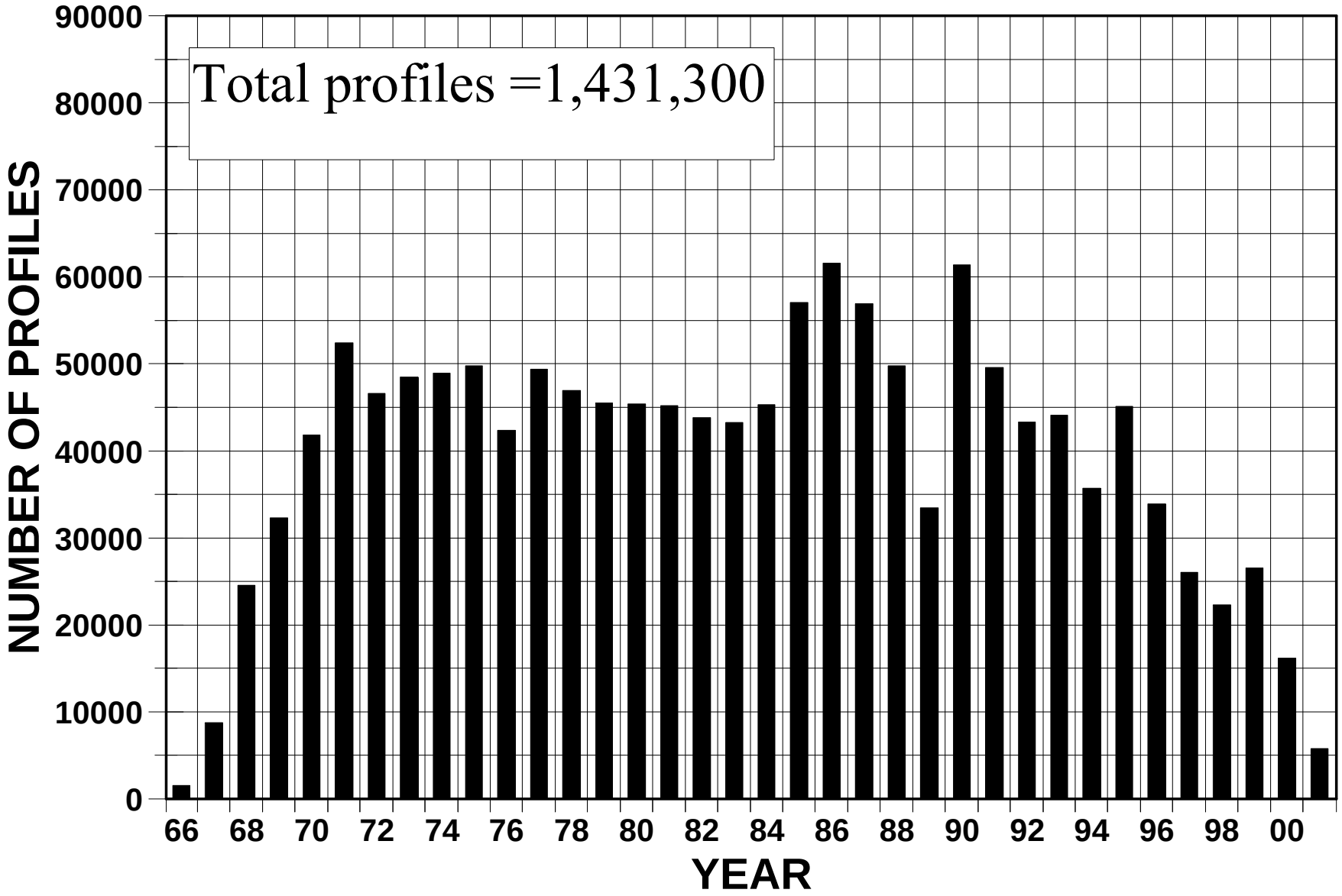

Fig. 7 Time series of XBT profiles in WOD01 for the northern hemisphere as a function of year.

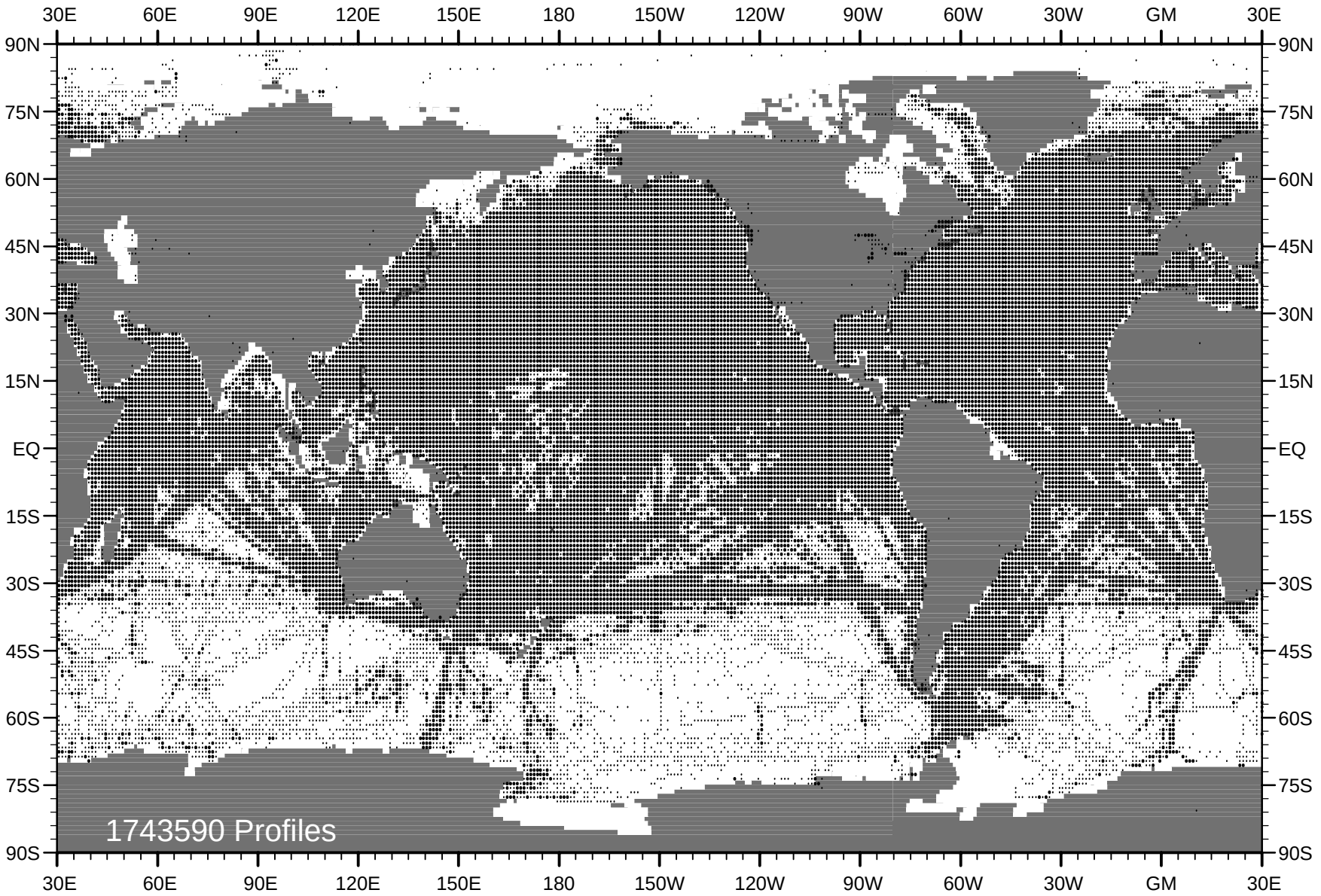

Fig. 8 Distribution of all profiles in the XBT files of WOD01.
Dots show location of 1-degree squares containing any data.

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5. APPENDIX B: DISTRIBUTIONS FOR INDIVIDUAL YEARS OF ALL XBT PROFILES IN WOD01

This appendix contains yearly data distributions of all XBT profile data contained in WOD98. These maps provide some history of the observational progress of the field of oceanography. They also serve as indicators of whether or not a particular data set from a scientist or institution is part of the NODC/WDC archive. The exchange of information provided by the publication of such maps has provided us with valuable information about deficiencies in the database. The locations of all WOD01 XBT profiles are plotted including profiles that may be erroneously located over land. However, WOD01 contains some profiles from various lakes so care should be exercised in the use of these profiles and the determination as to whether they represent errors in locations.

For all figures in Appendix A, a small dot indicates a one-degree square containing from one to four profiles and a large dot indicates five or more profiles.

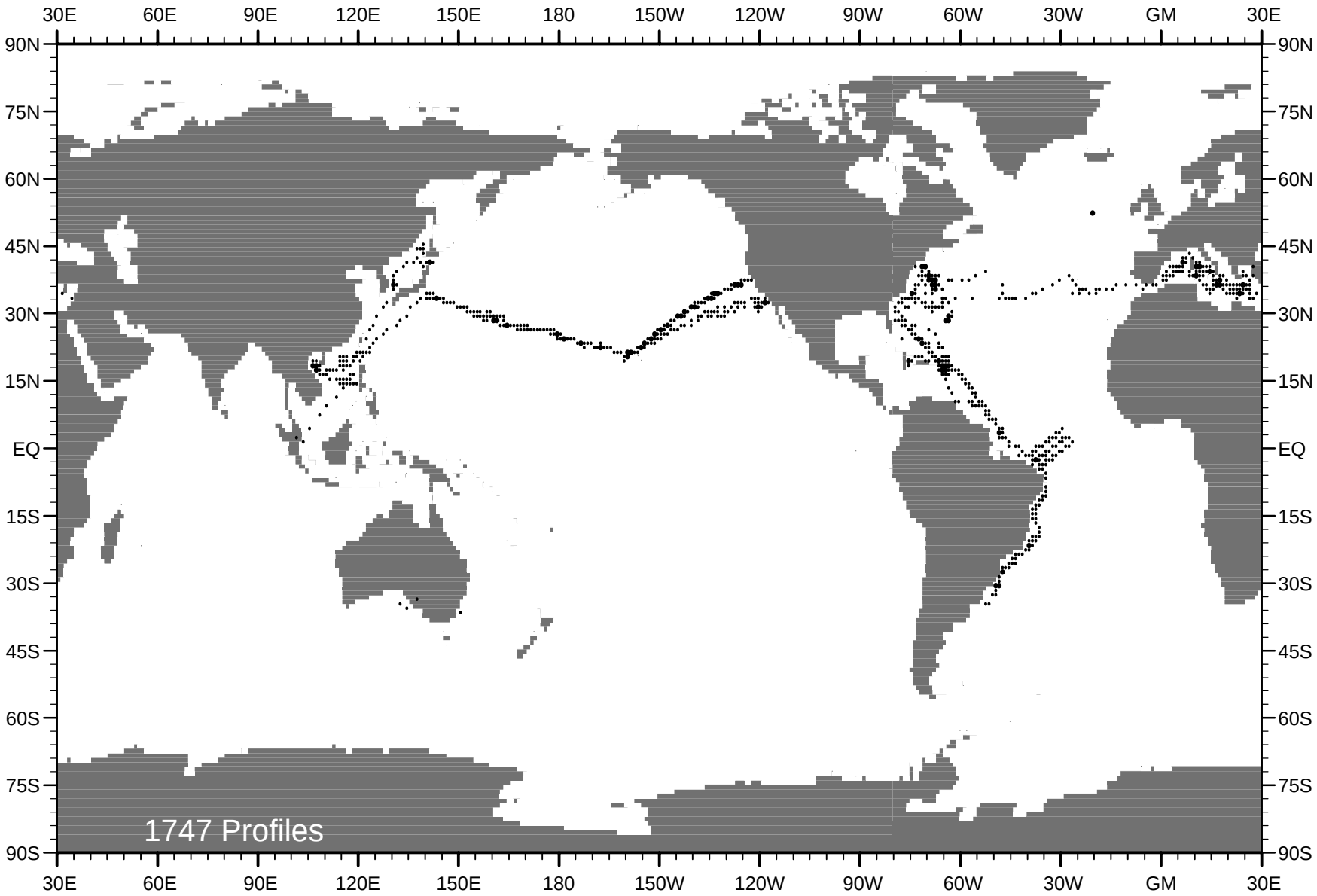


Fig. B1 WOD01 XBT profile distribution for year 1966 .

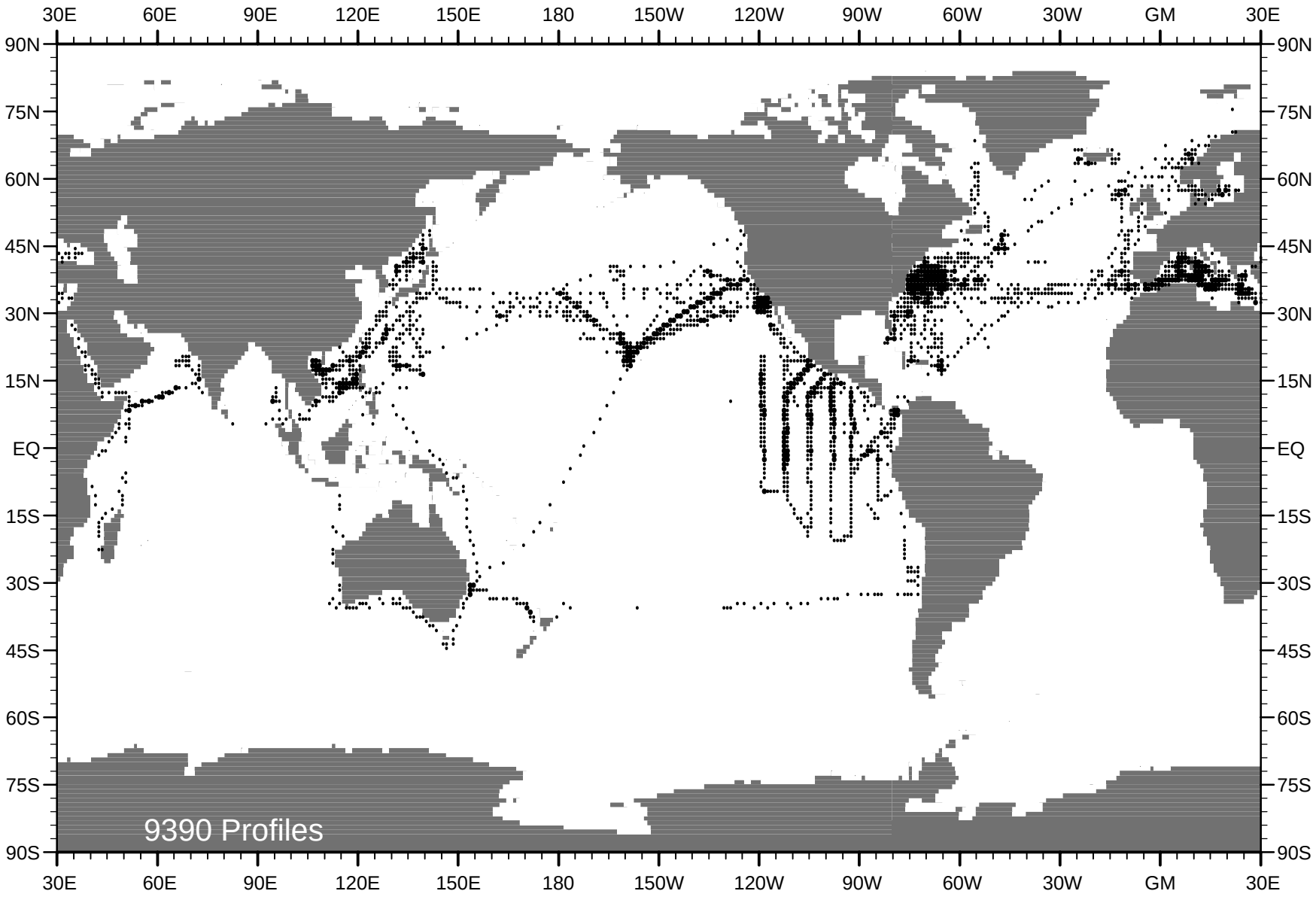


Fig. B2 WOD01 XBT profile distribution for year 1967 .

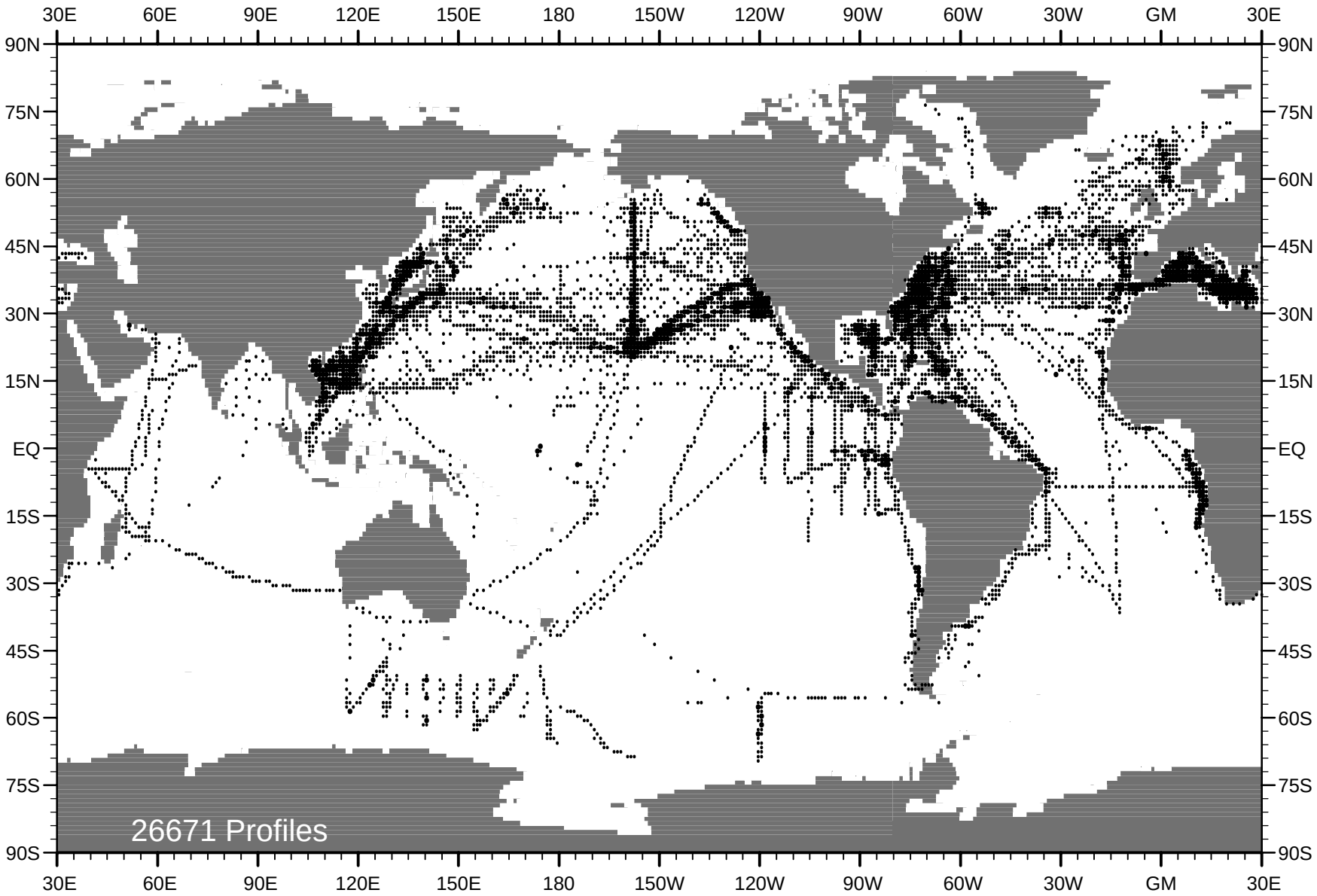


Fig. B3 WOD01 XBT profile distribution for year 1968 .

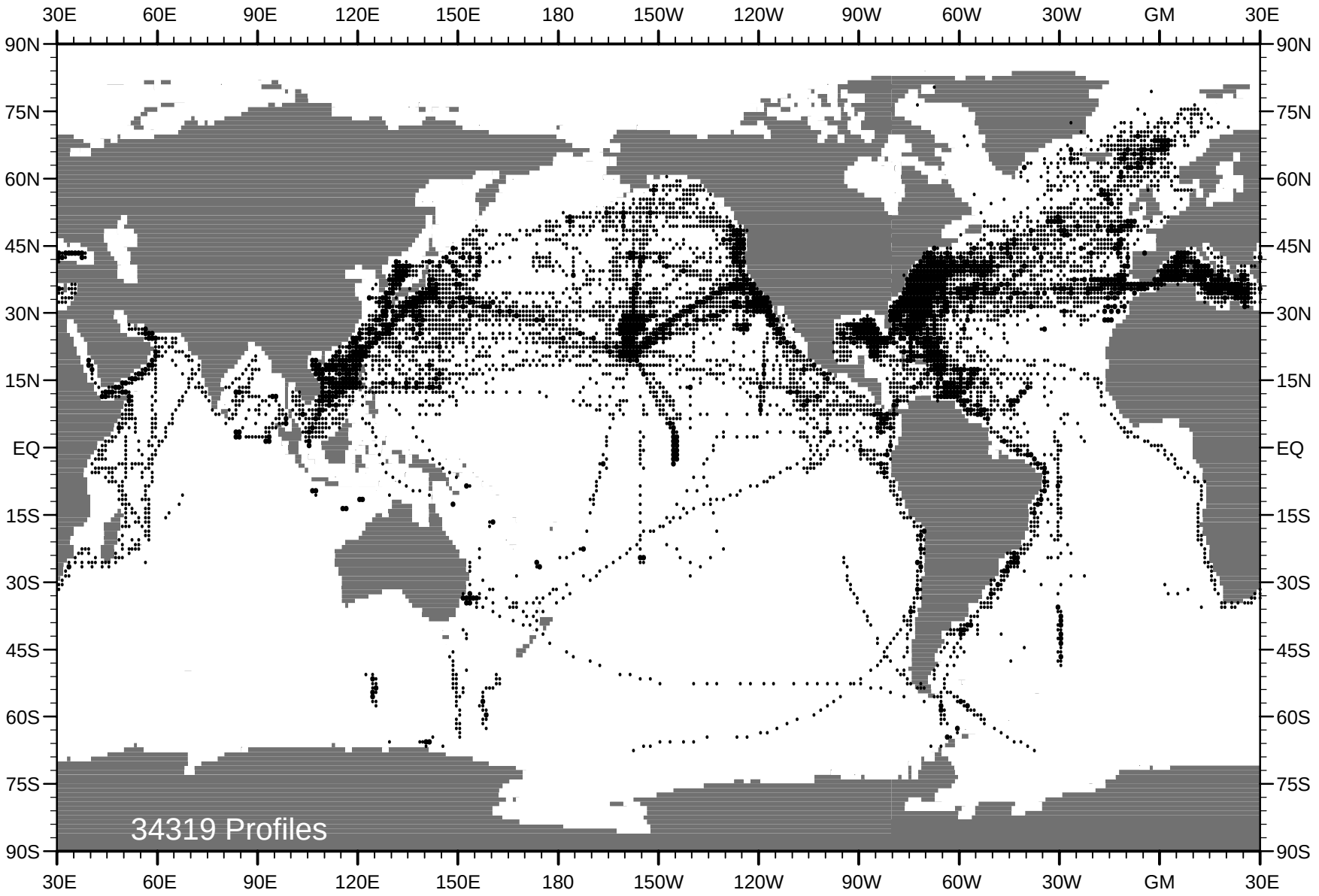


Fig. B4 WOD01 XBT profile distribution for year 1969 .

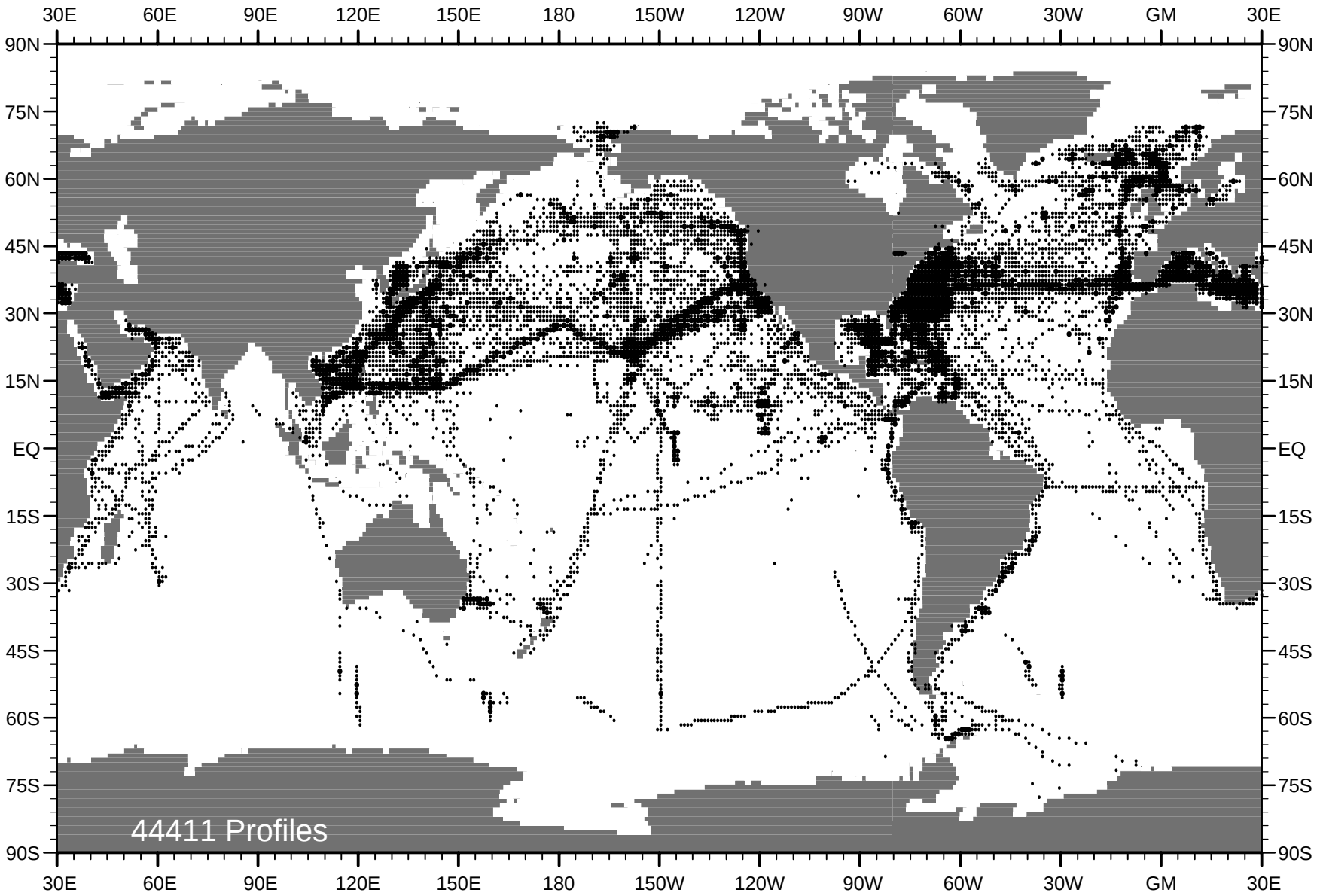


Fig. B5 WOD01 XBT profile distribution for year 1970 .

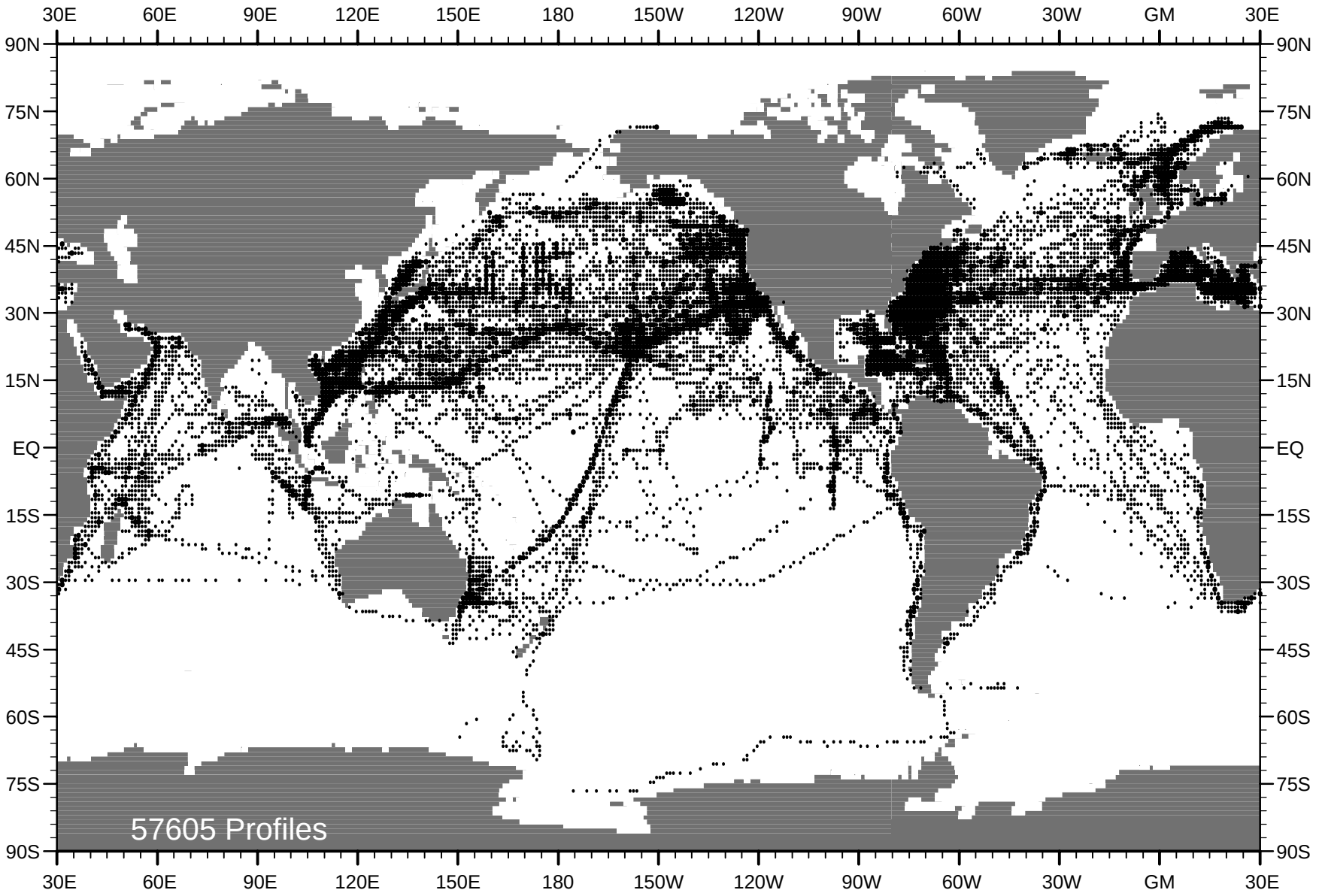


Fig. B6 WOD01 XBT profile distribution for year 1971 .

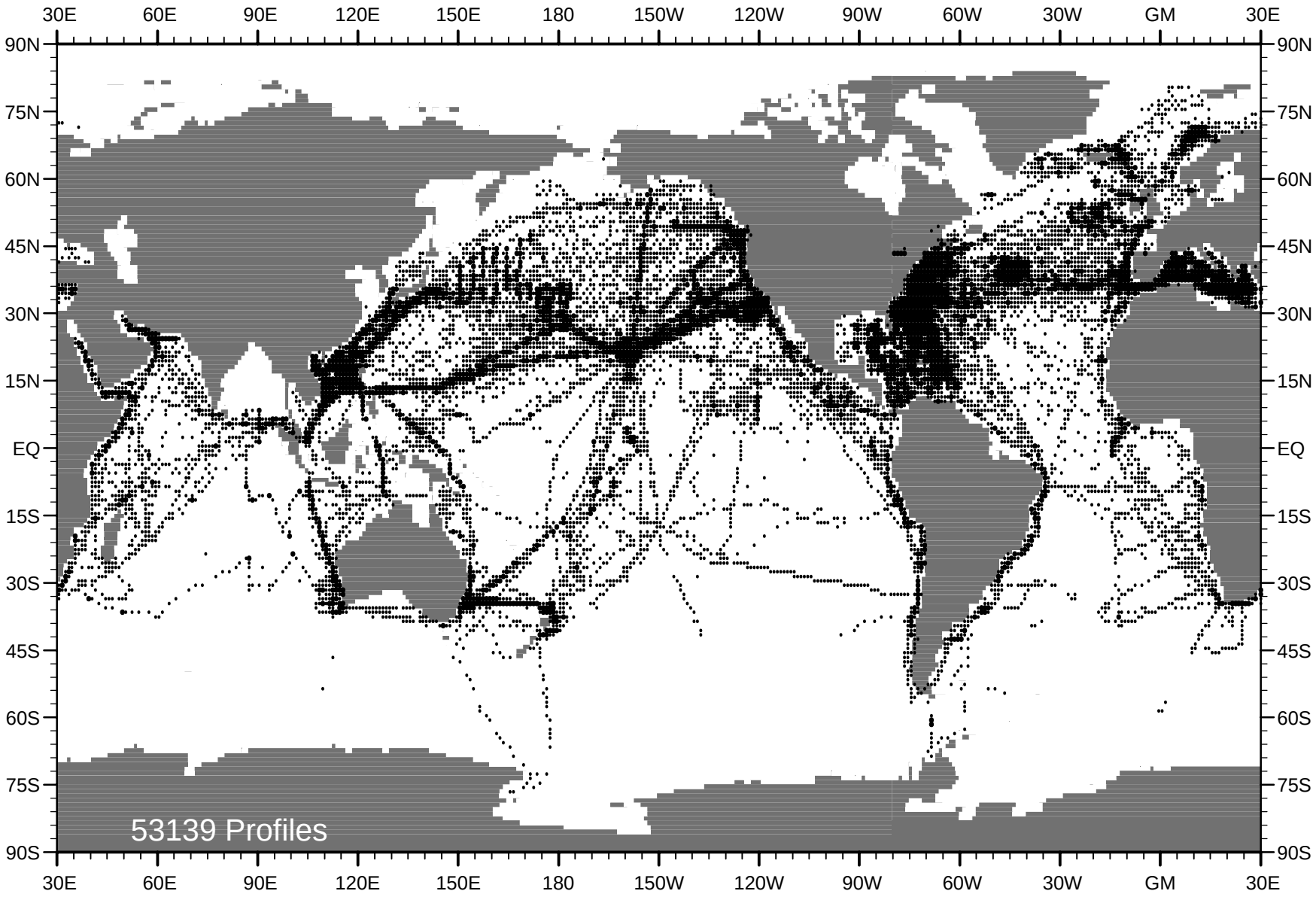


Fig. B7 WOD01 XBT profile distribution for year 1972 .

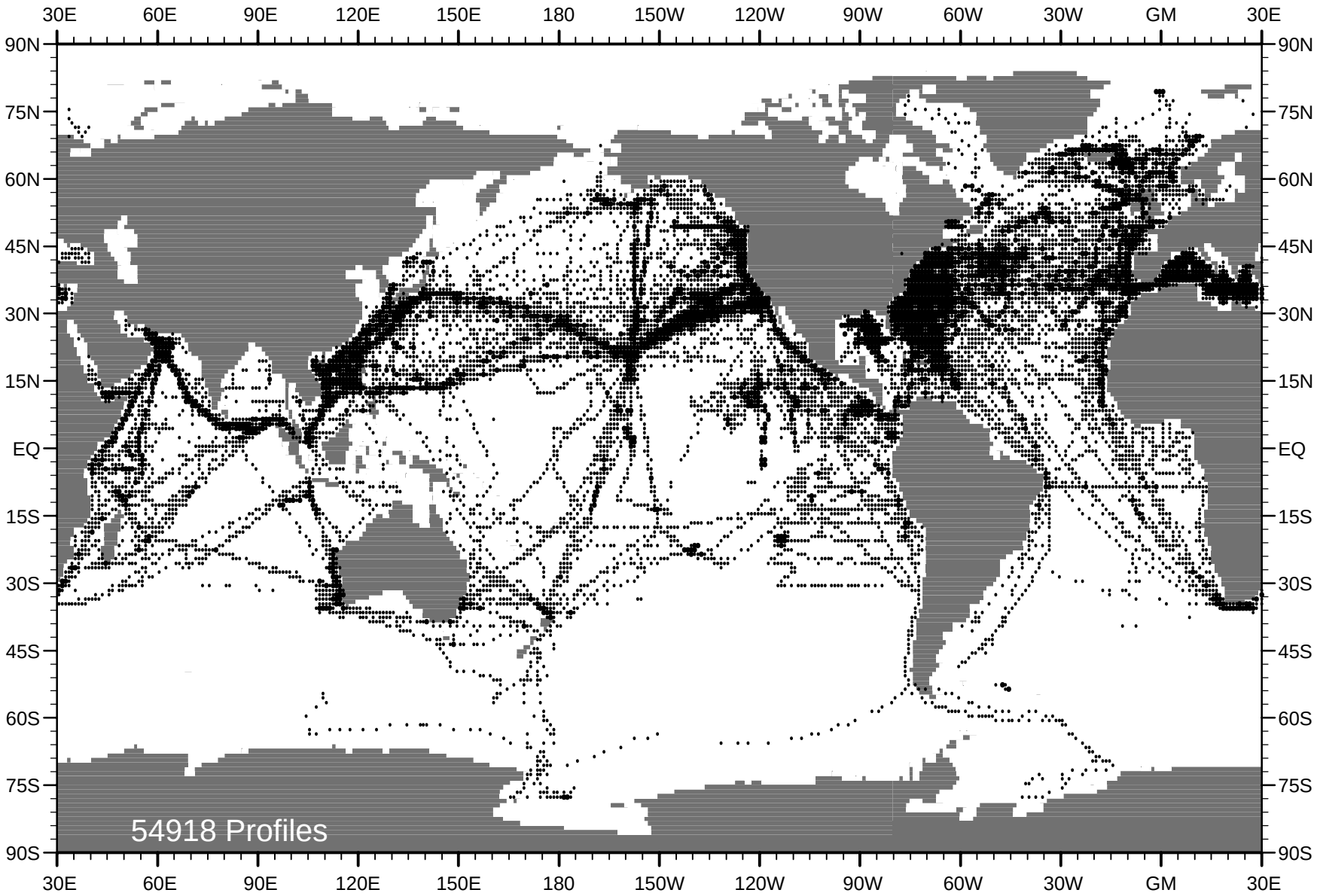


Fig. B8 WOD01 XBT profile distribution for year 1973 .

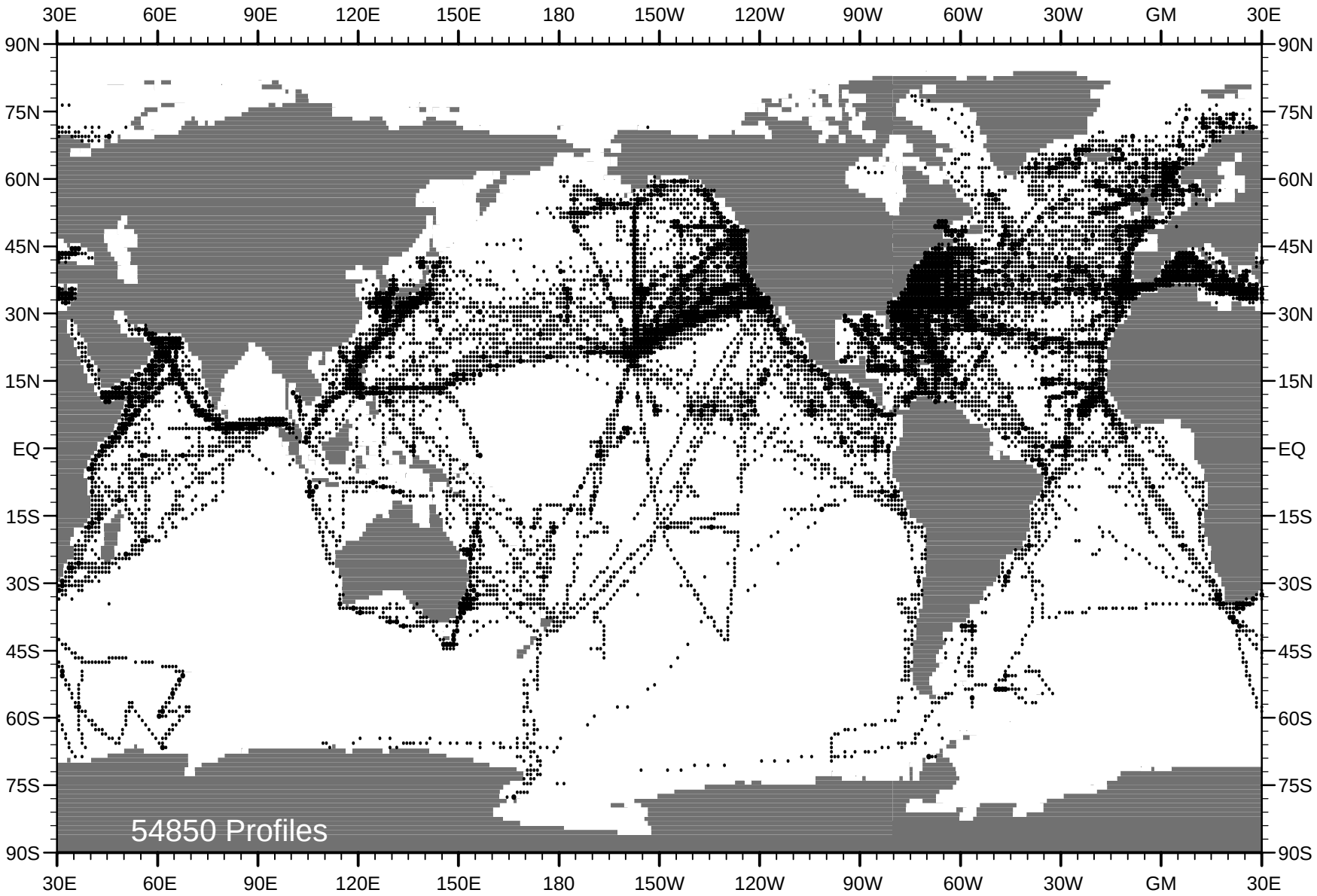


Fig. B9 WOD01 XBT profile distribution for year 1974 .

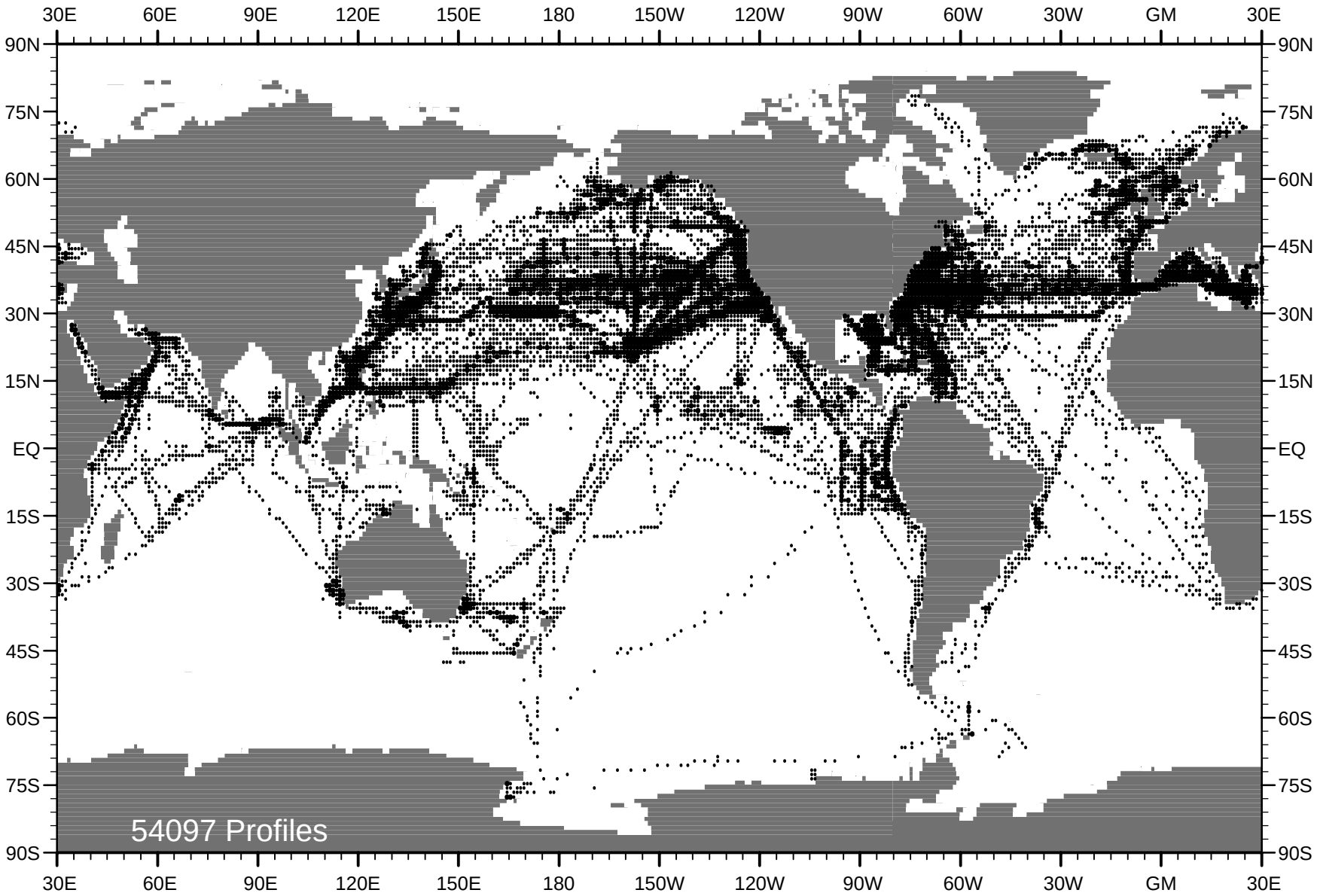


Fig. B10 WOD01 XBT profile distribution for year 1975 .

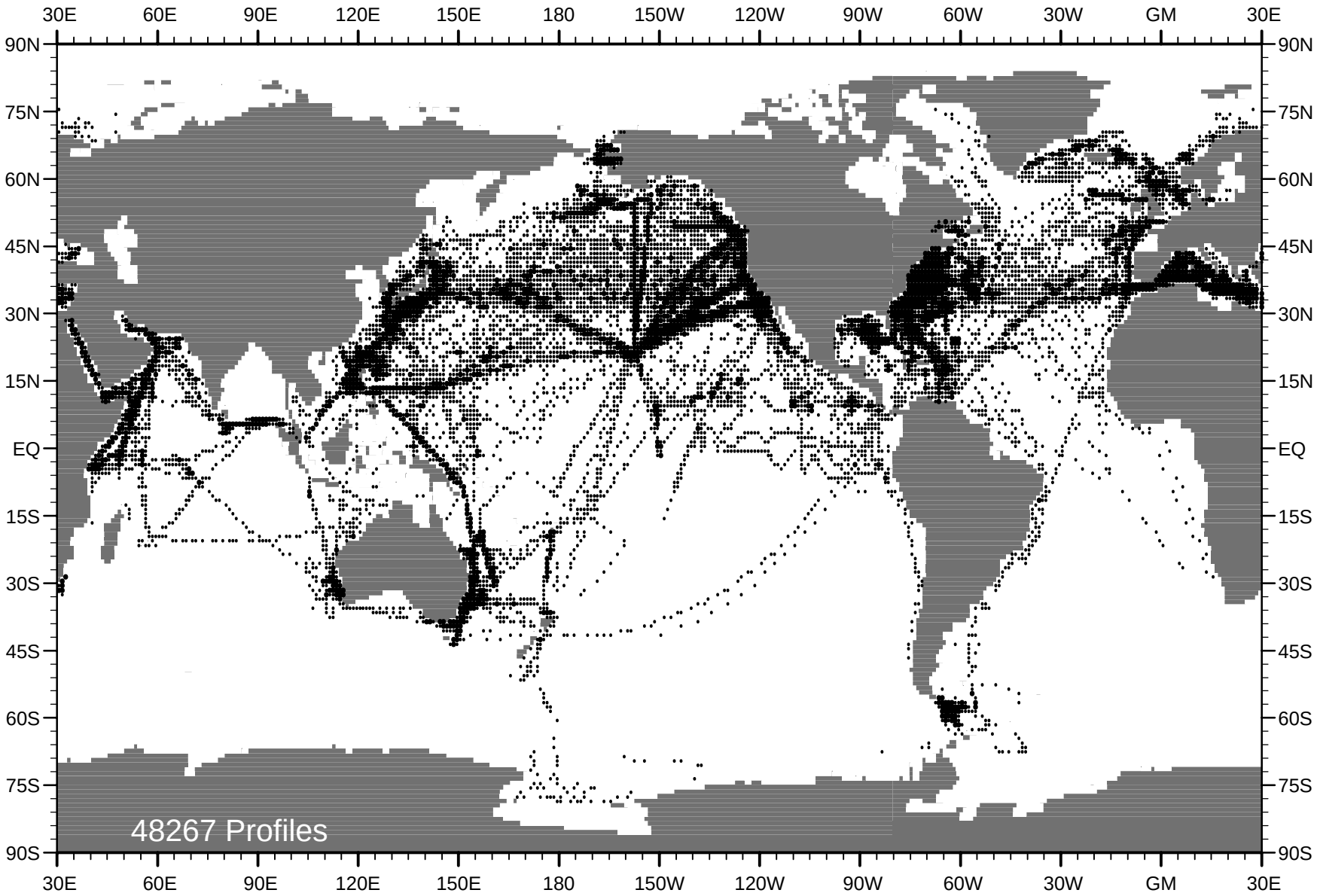


Fig. B11 WOD01 XBT profile distribution for year 1976 .

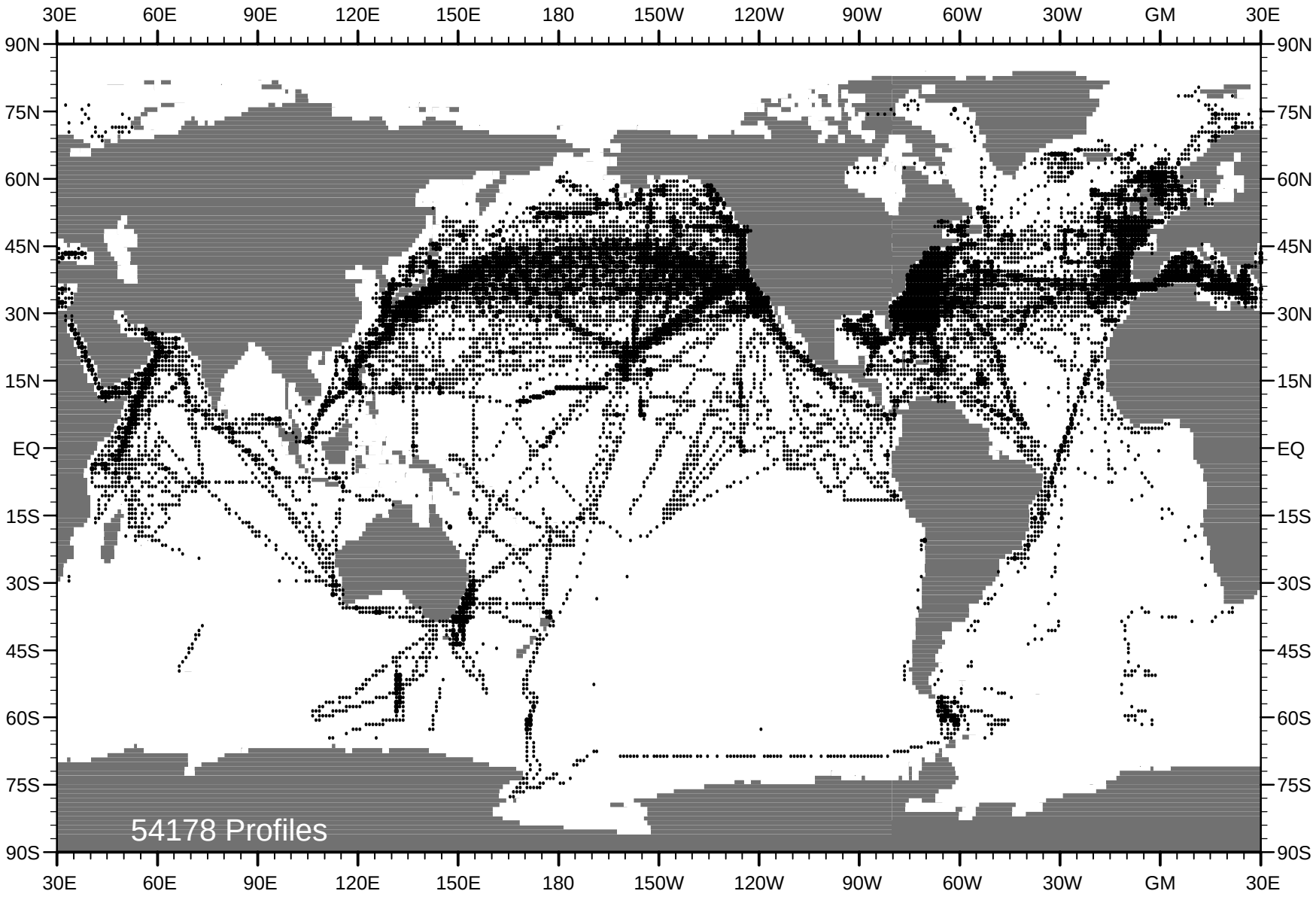


Fig. B12 WOD01 XBT profile distribution for year 1977 .

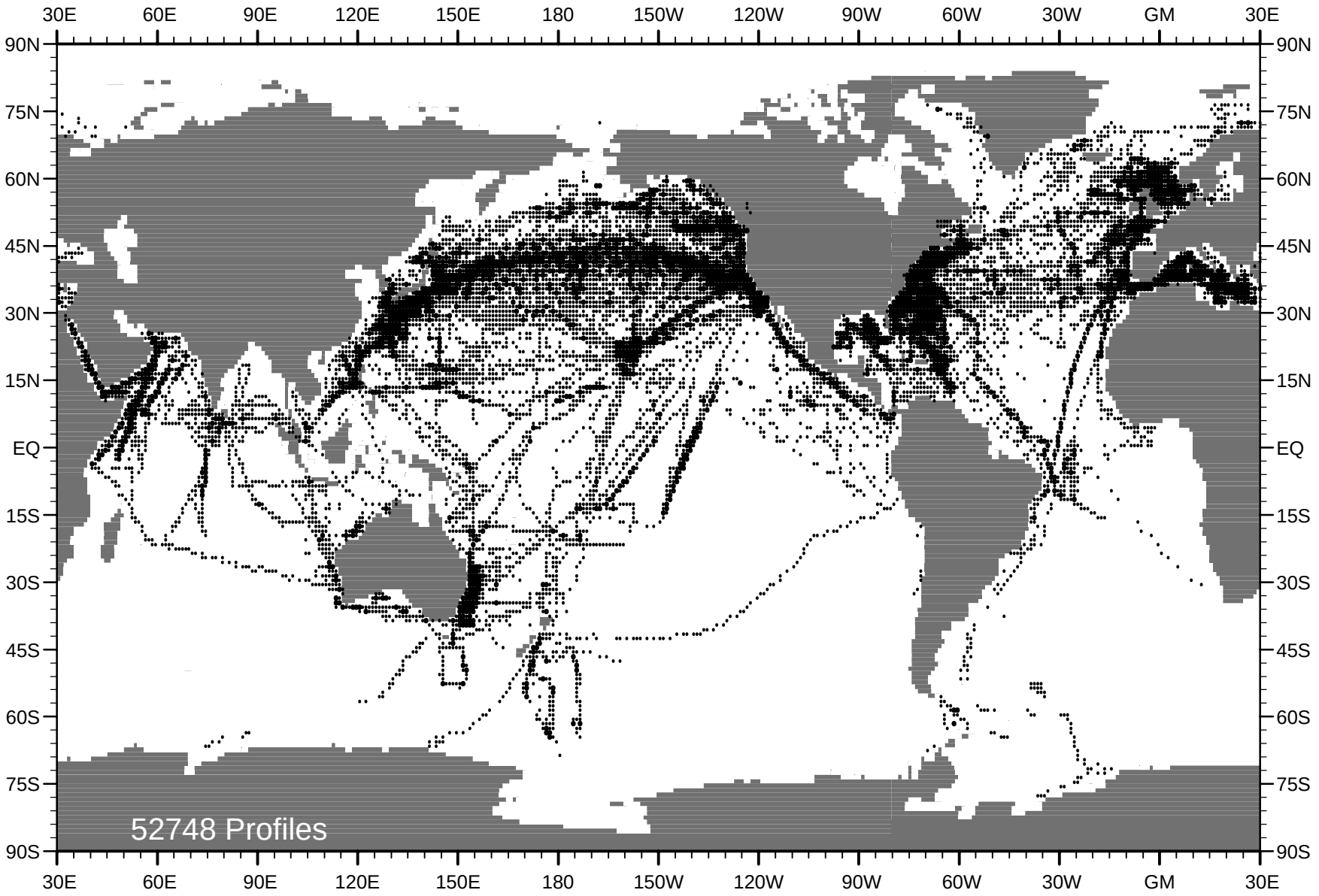


Fig. B13 WOD01 XBT profile distribution for year 1978 .

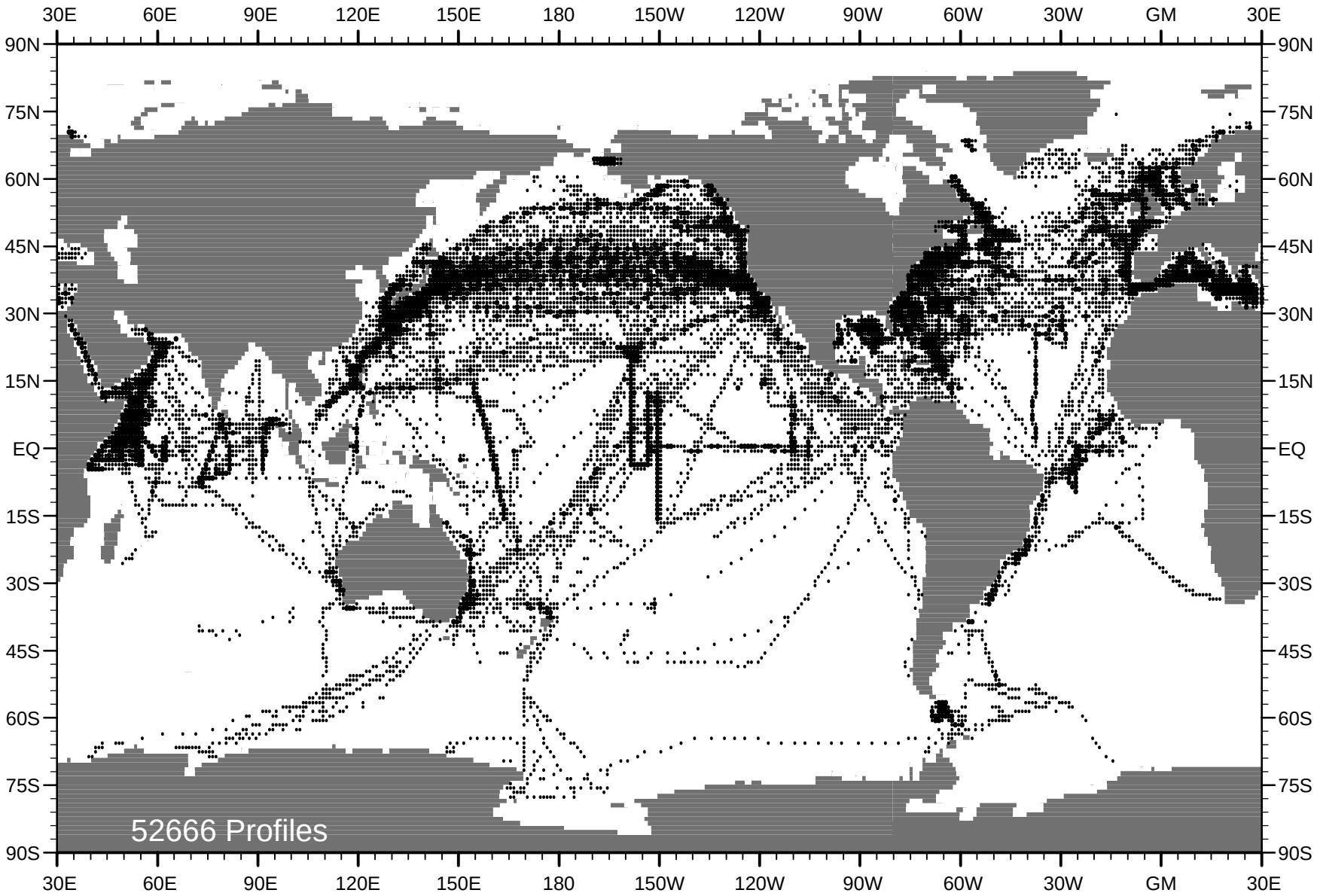


Fig. B14 WOD01 XBT profile distribution for year 1979 .

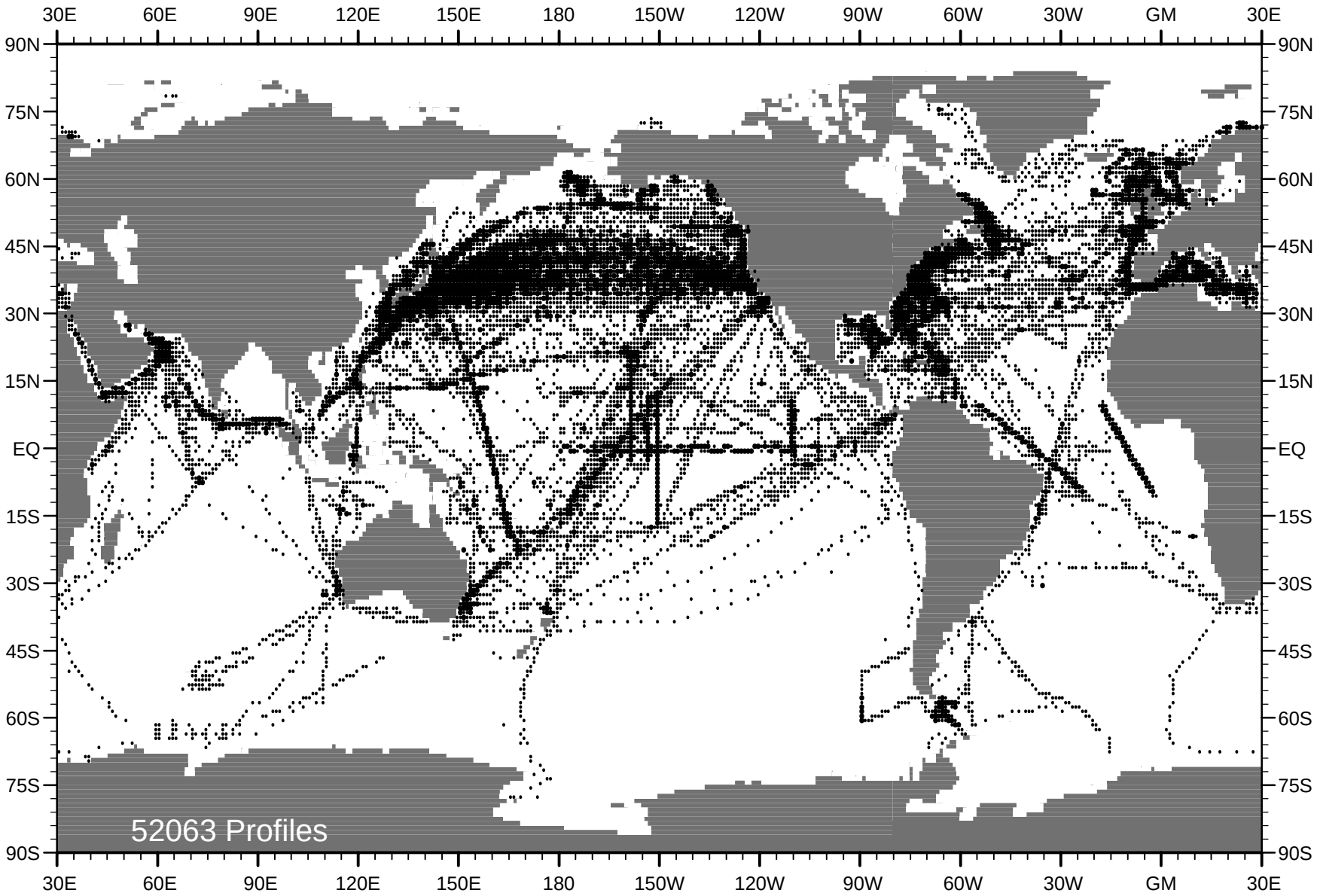


Fig. B15 WOD01 XBT profile distribution for year 1980 .

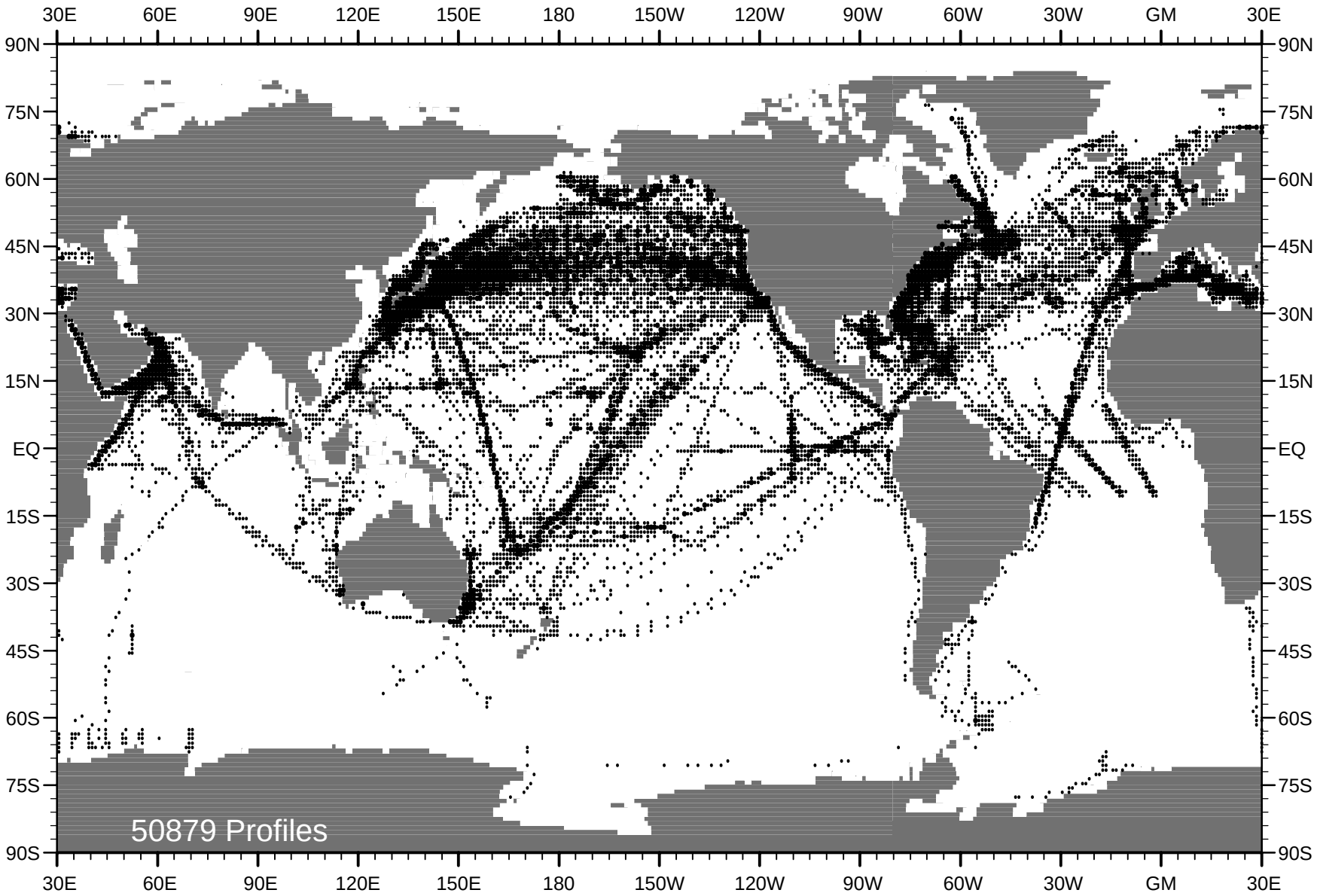


Fig. B16 WOD01 XBT profile distribution for year 1981 .

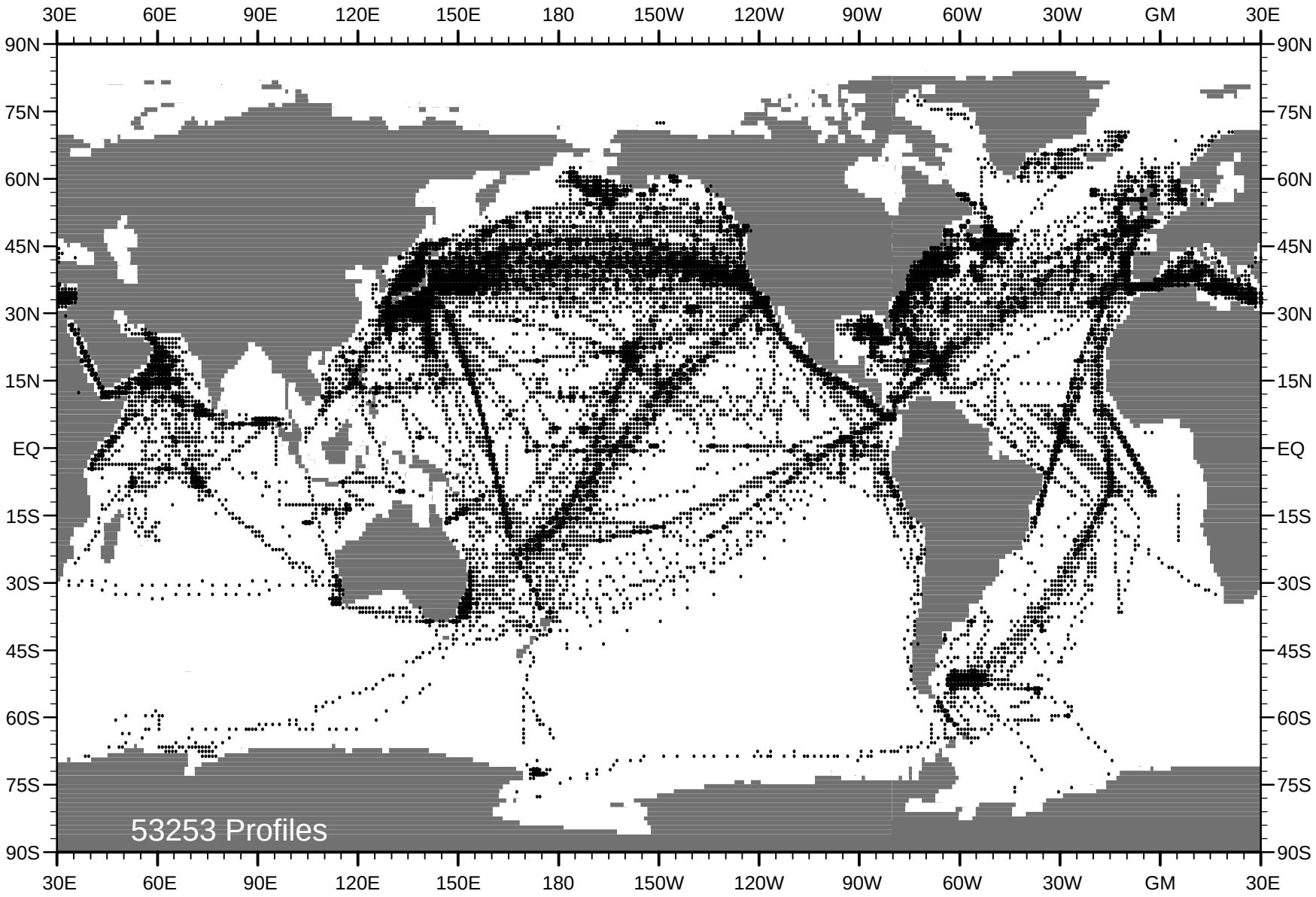


Fig. B17 WOD01 XBT profile distribution for year 1982 .

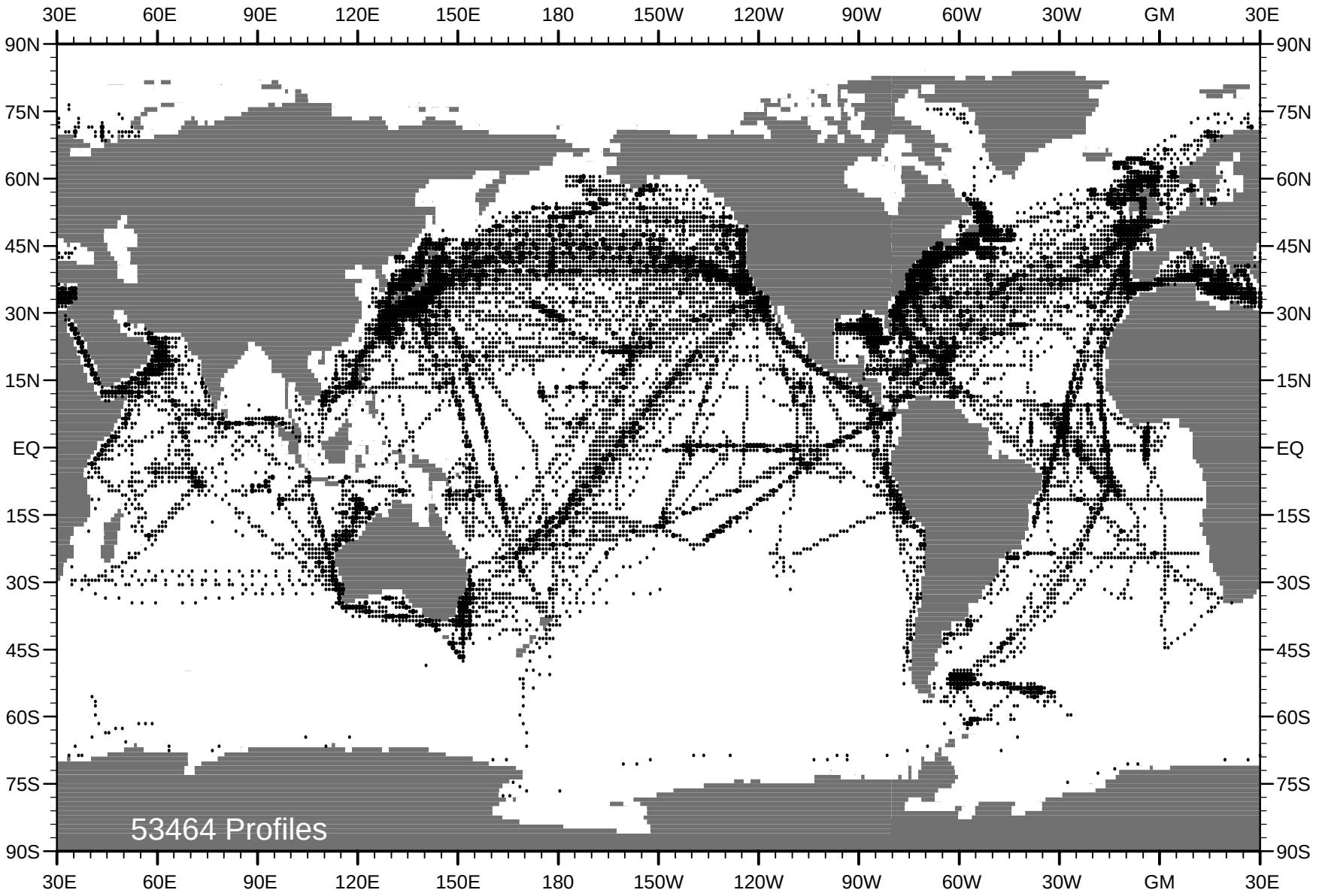


Fig. B18 WOD01 XBT profile distribution for year 1983 .

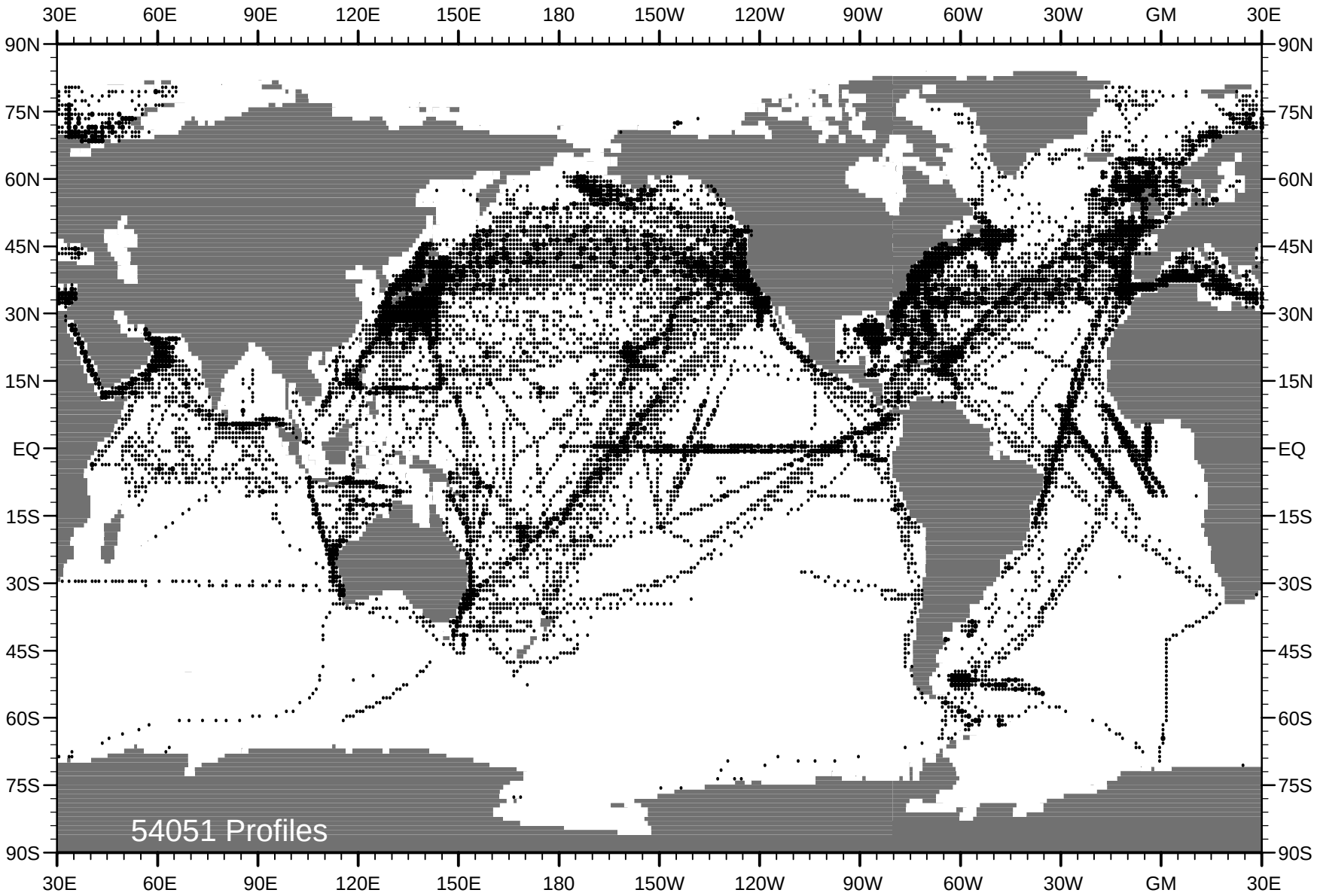
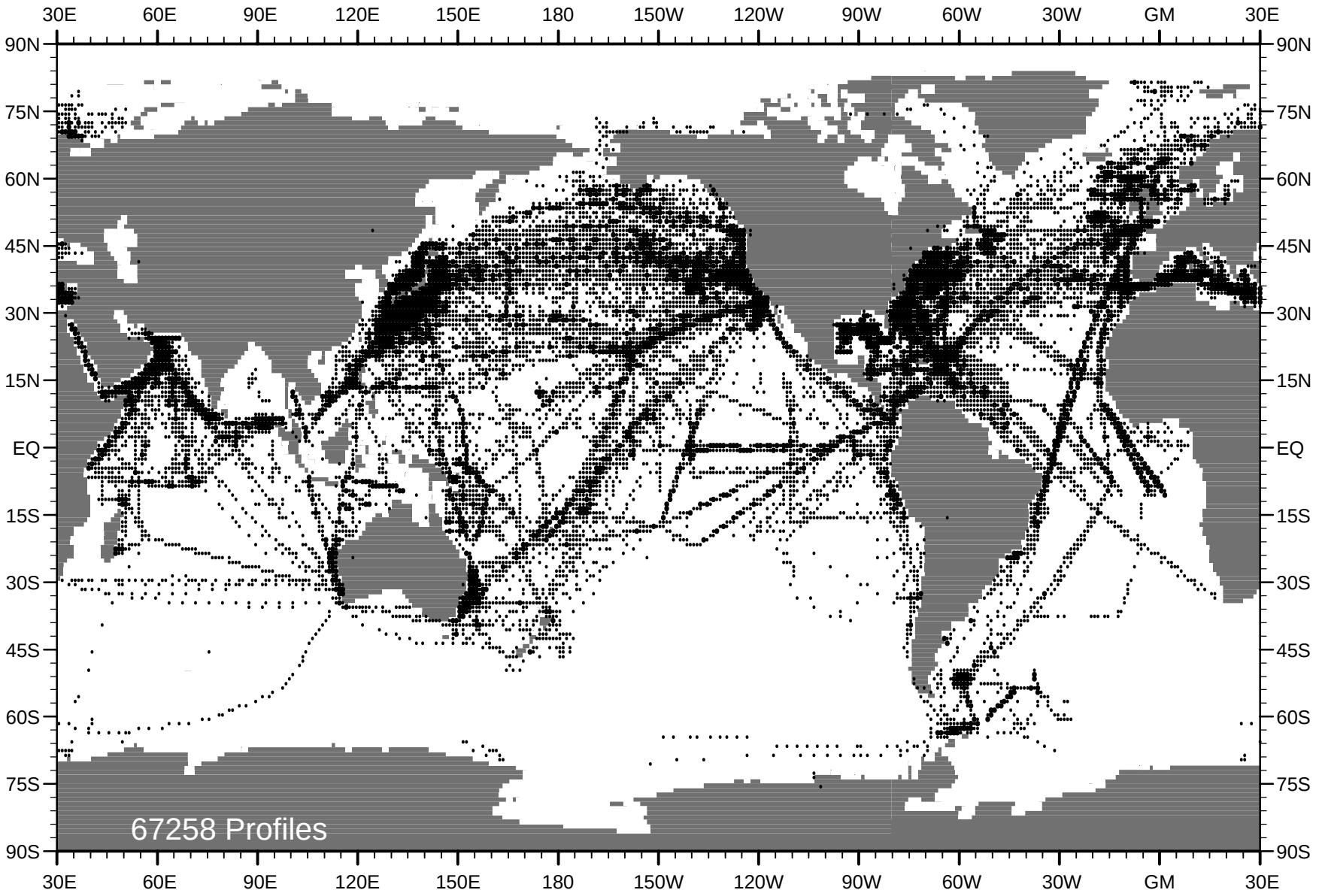


Fig. B19 WOD01 XBT profile distribution for year 1984 .



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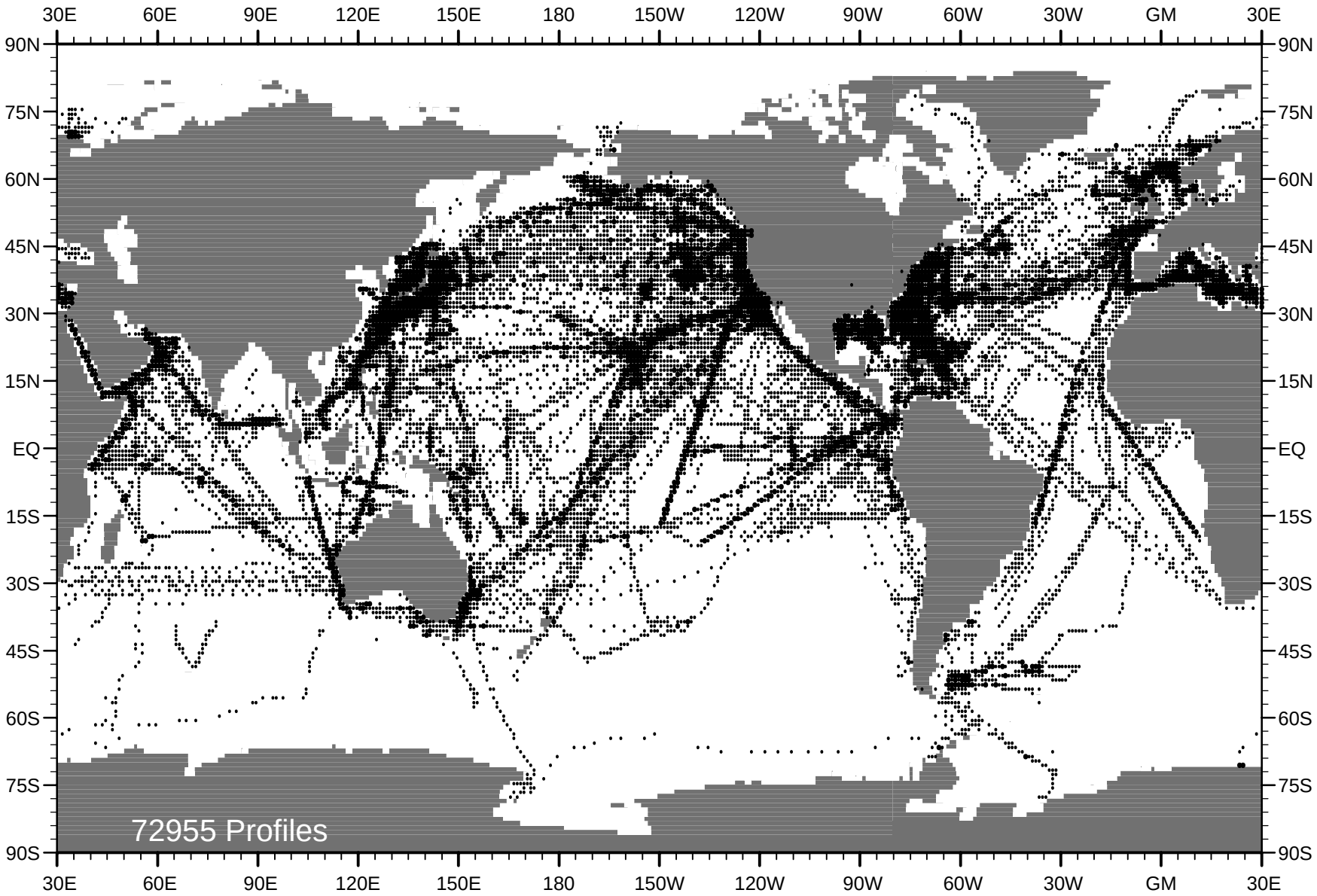

Fig. B21 WOD01 XBT profile distribution for year 1986 .

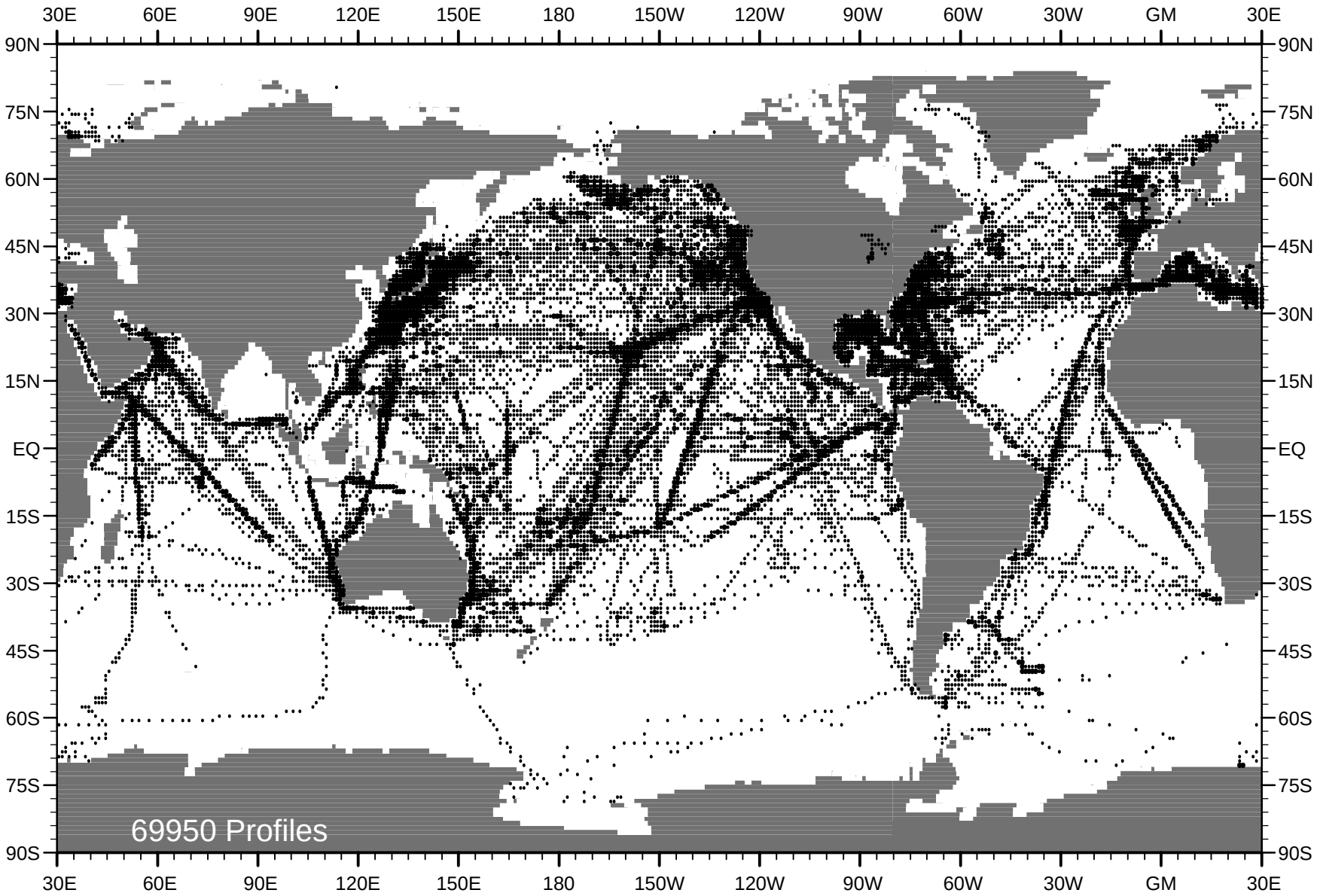

Fig. B22 WOD01 XBT profile distribution for year 1987 .

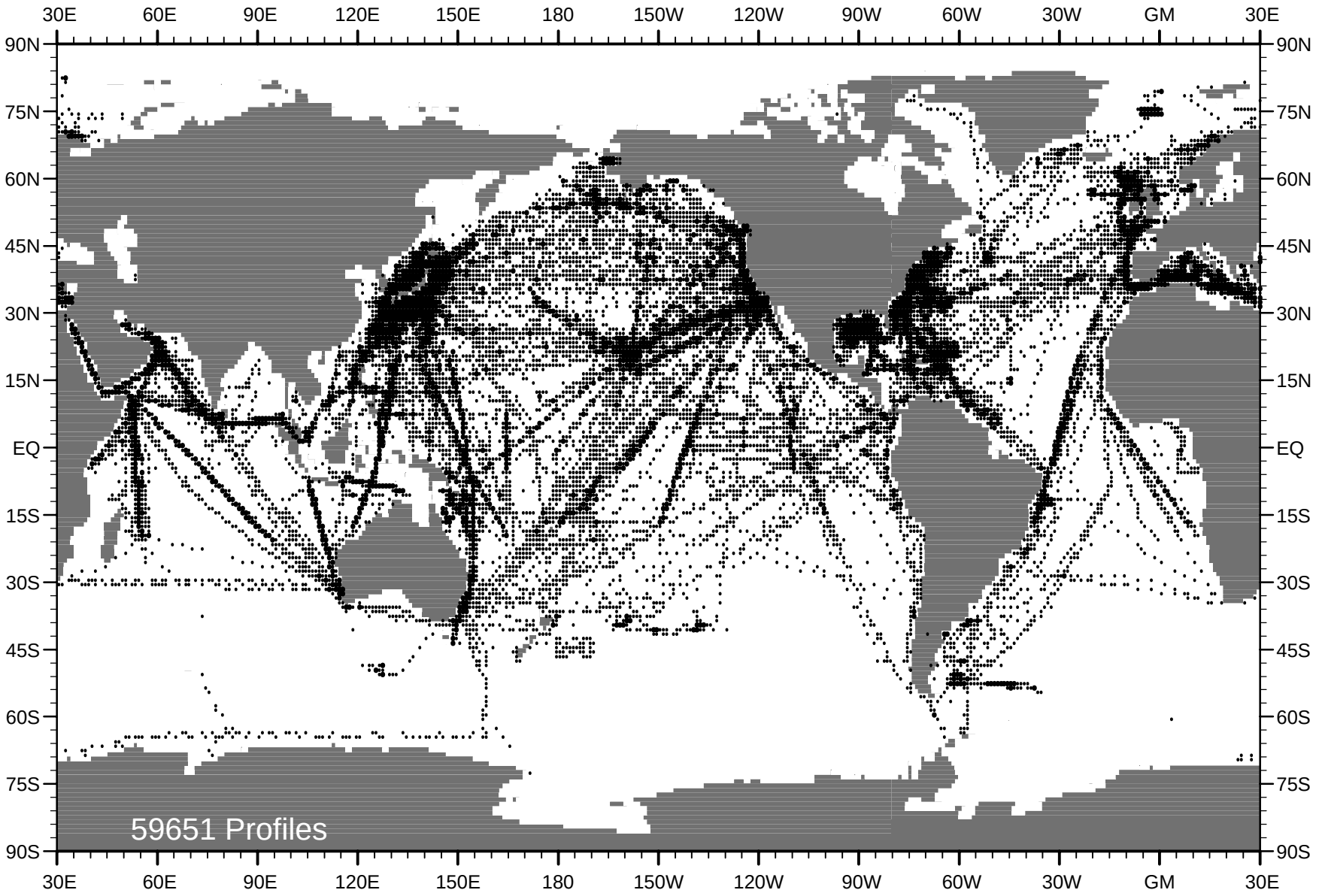

Fig. B23 WOD01 XBT profile distribution for year 1988 .

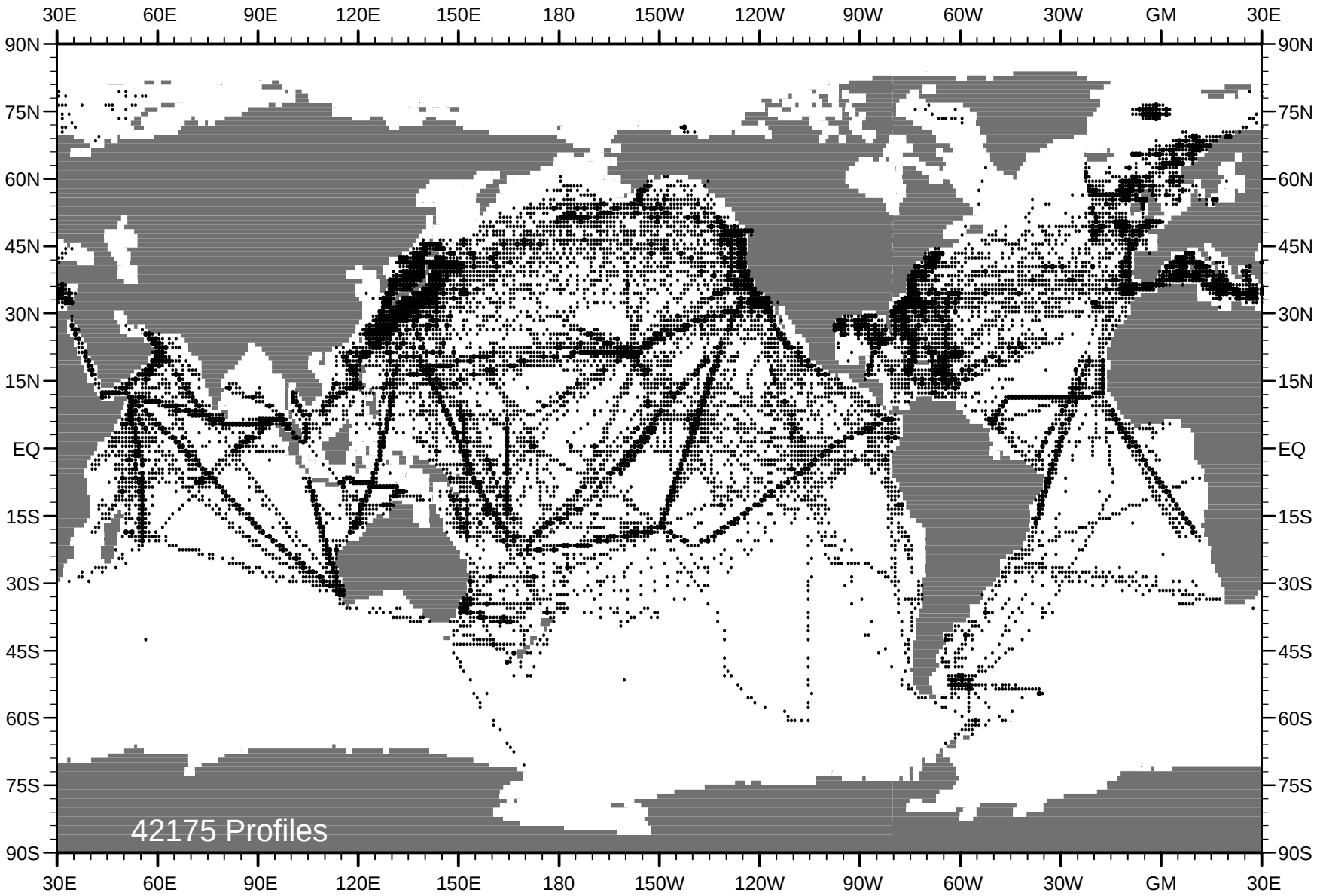

Fig. B24 WOD01 XBT profile distribution for year 1989 .

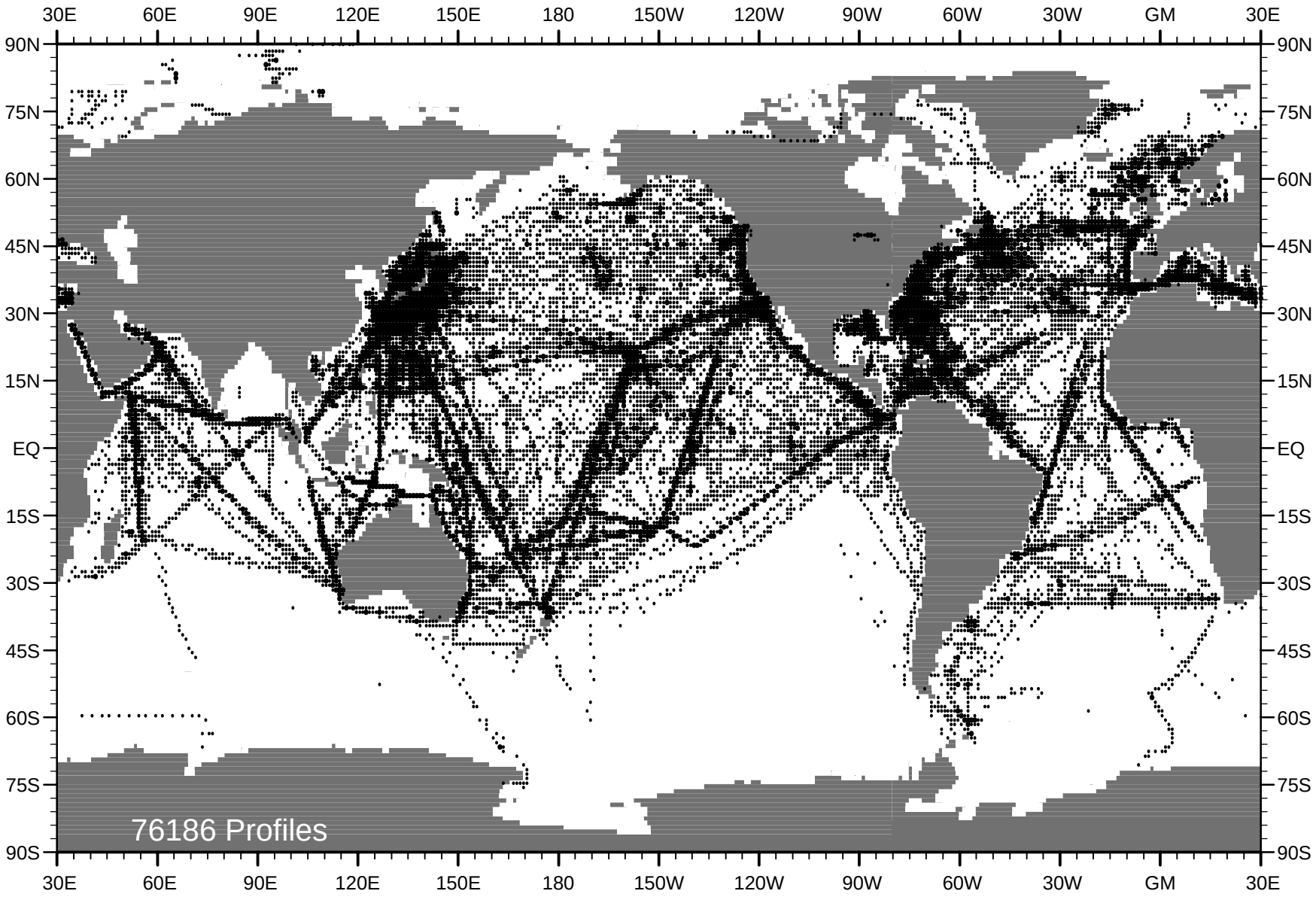

Fig. B25 WOD01 XBT profile distribution for year 1990 .

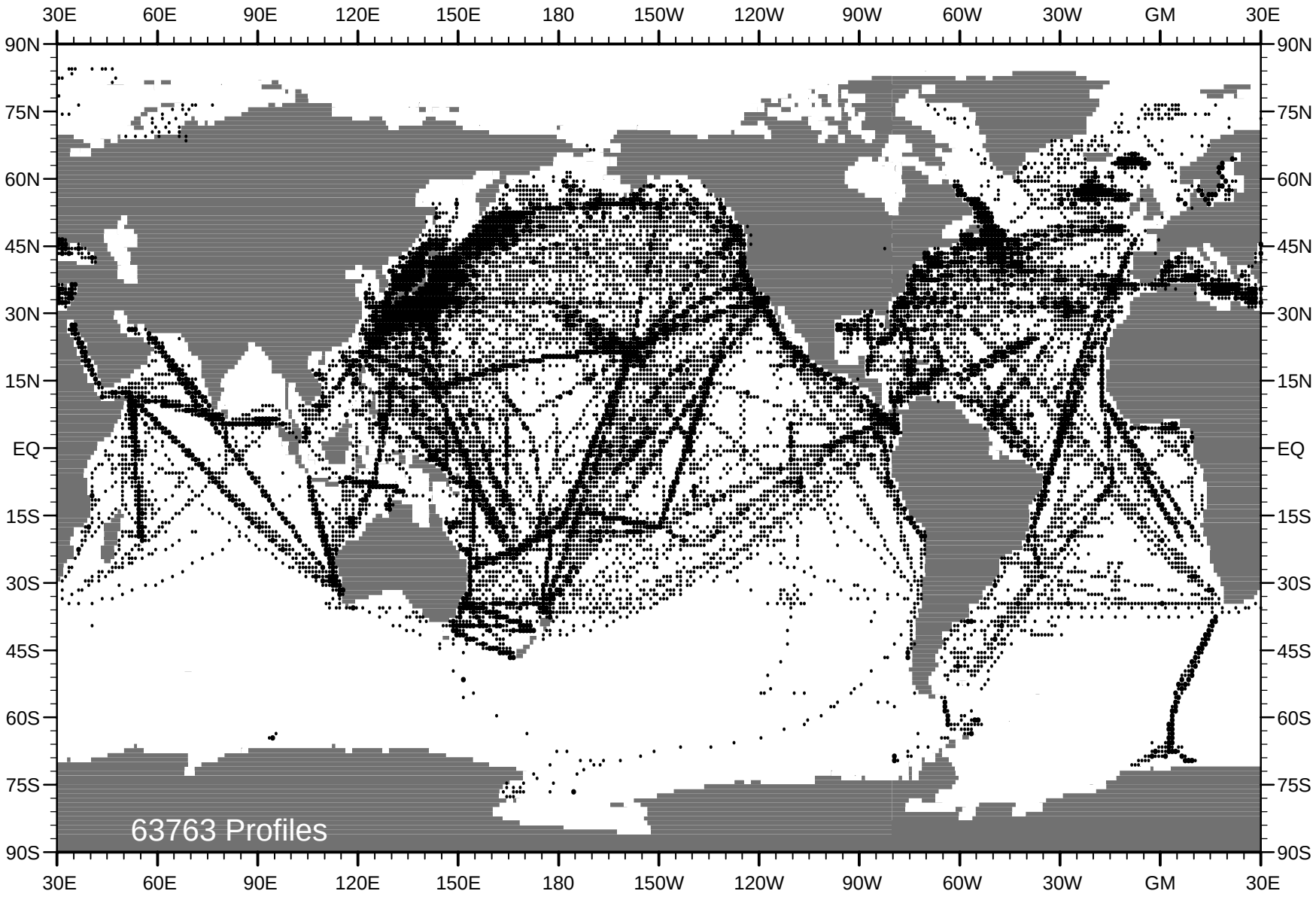

Fig. B26 WOD01 XBT profile distribution for year 1991 .

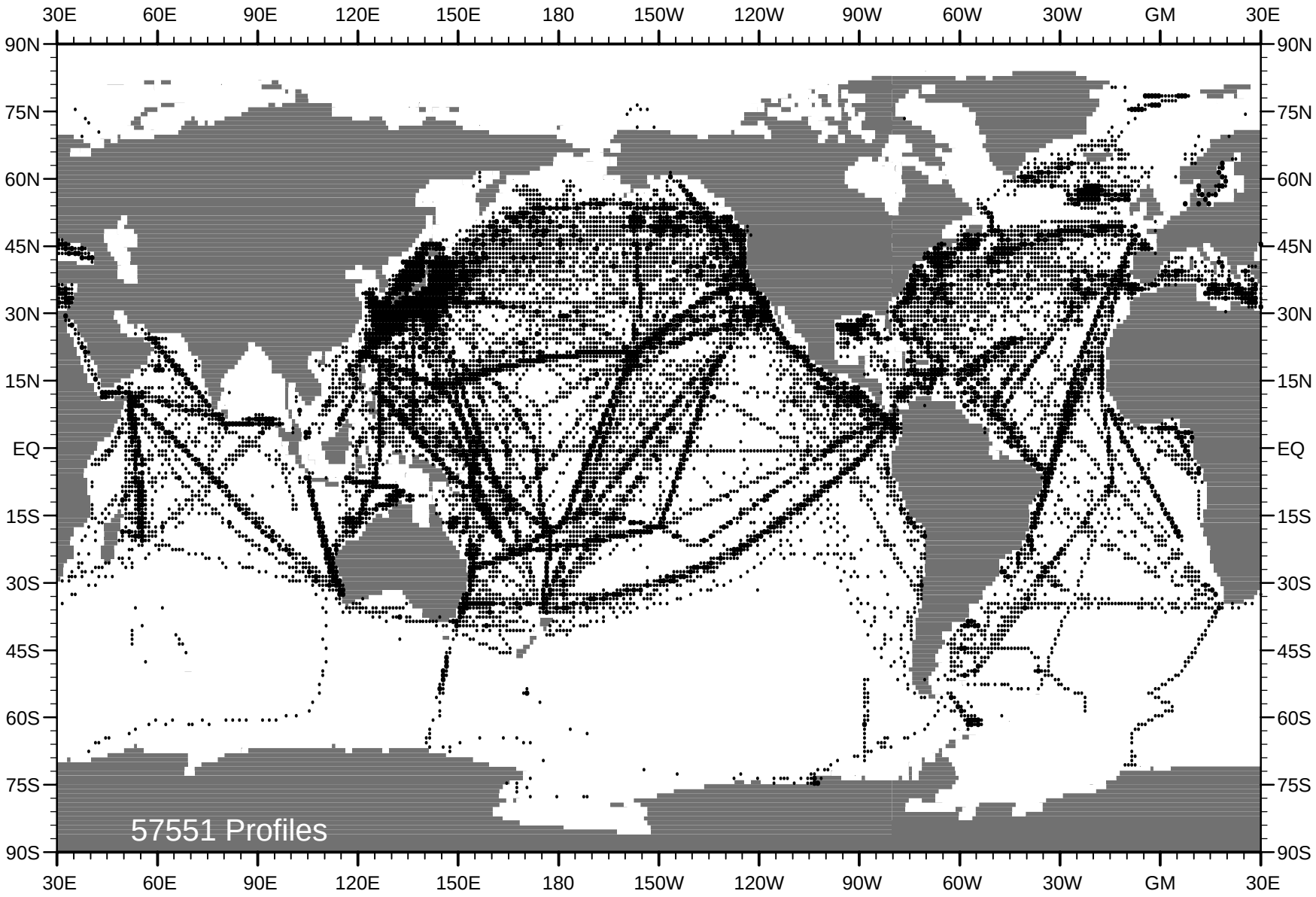

Fig. B27 WOD01 XBT profile distribution for year 1992 .

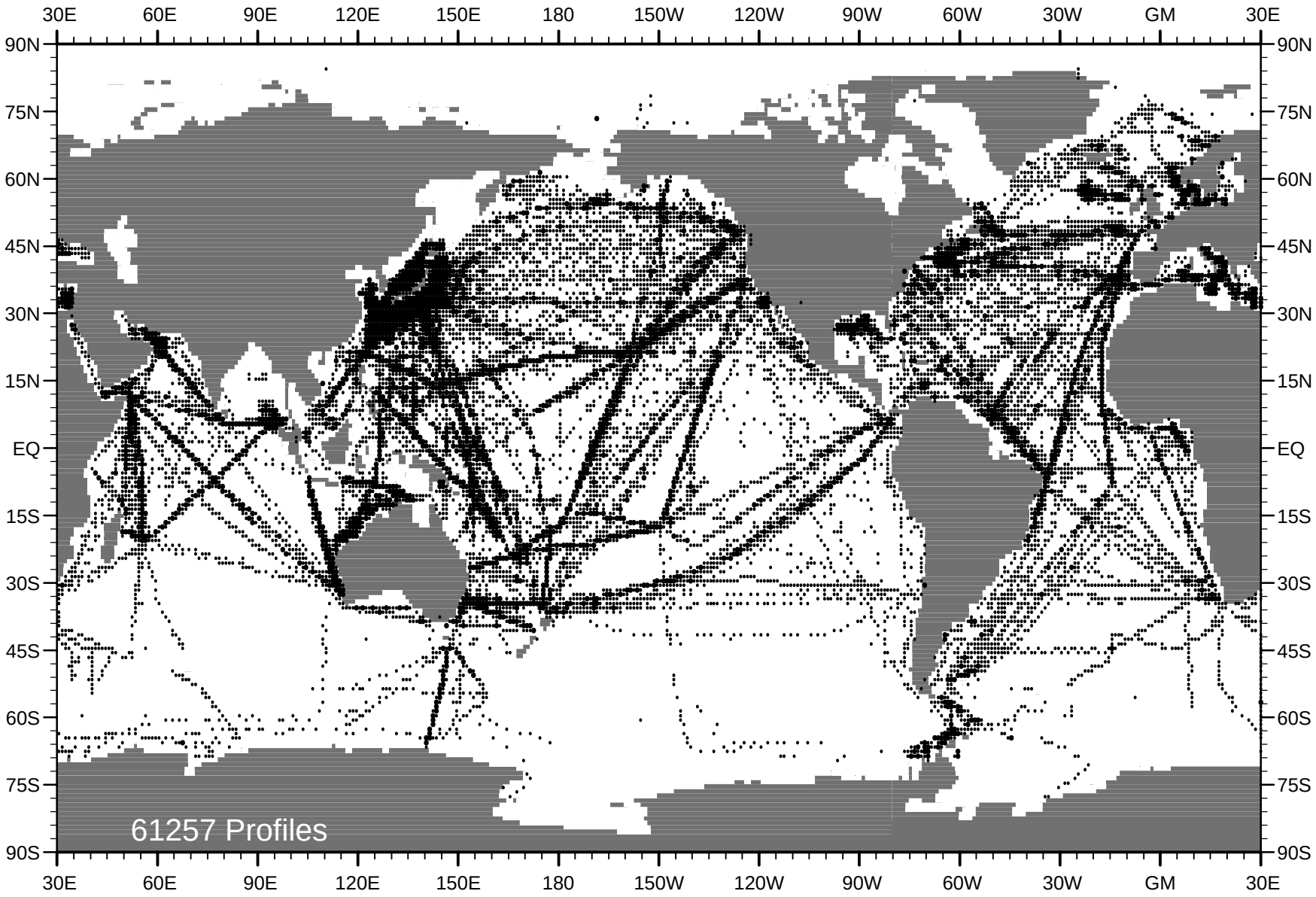

Fig. B28 WOD01 XBT profile distribution for year 1993 .

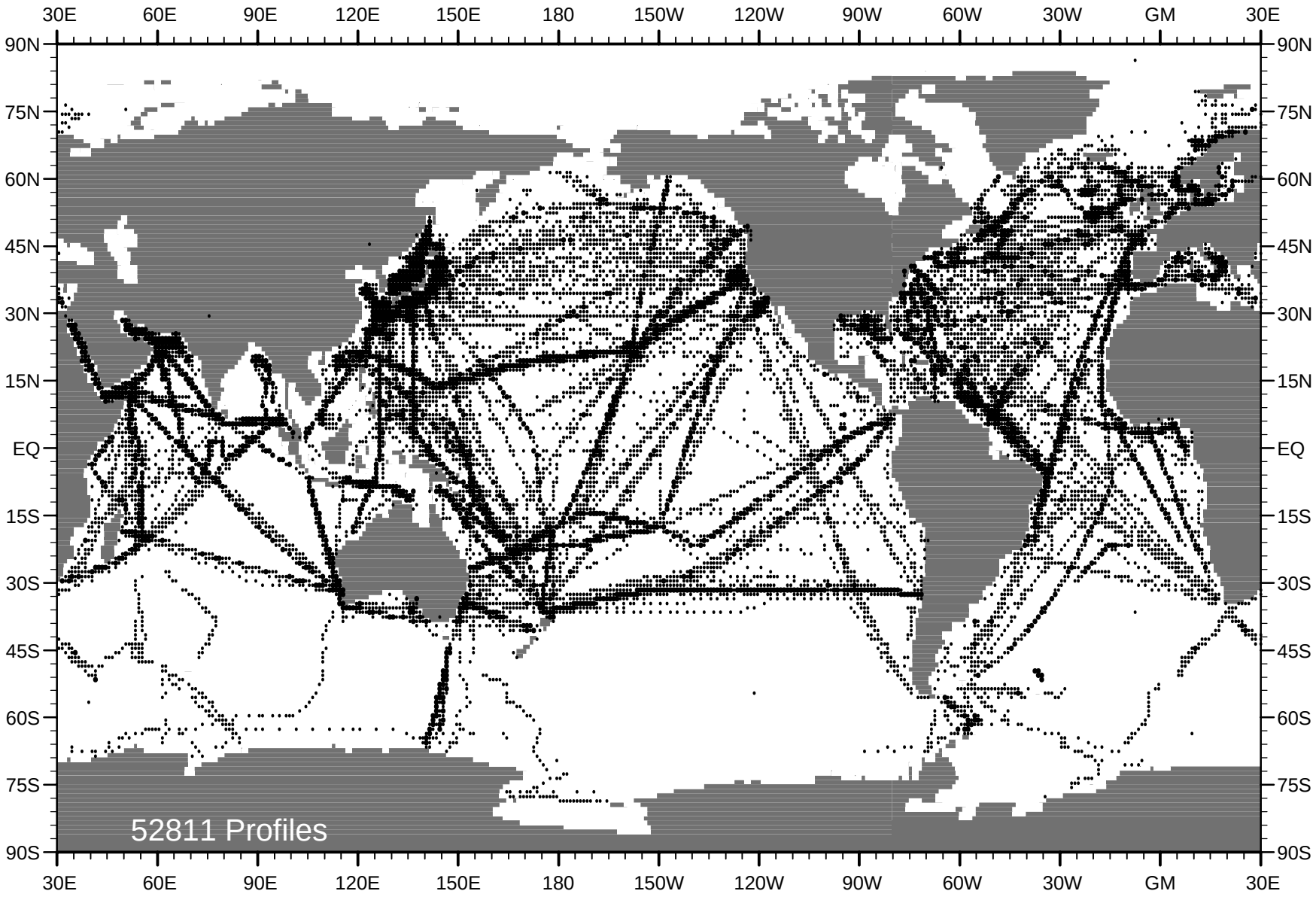

Fig. B29 WOD01 XBT profile distribution for year 1994 .

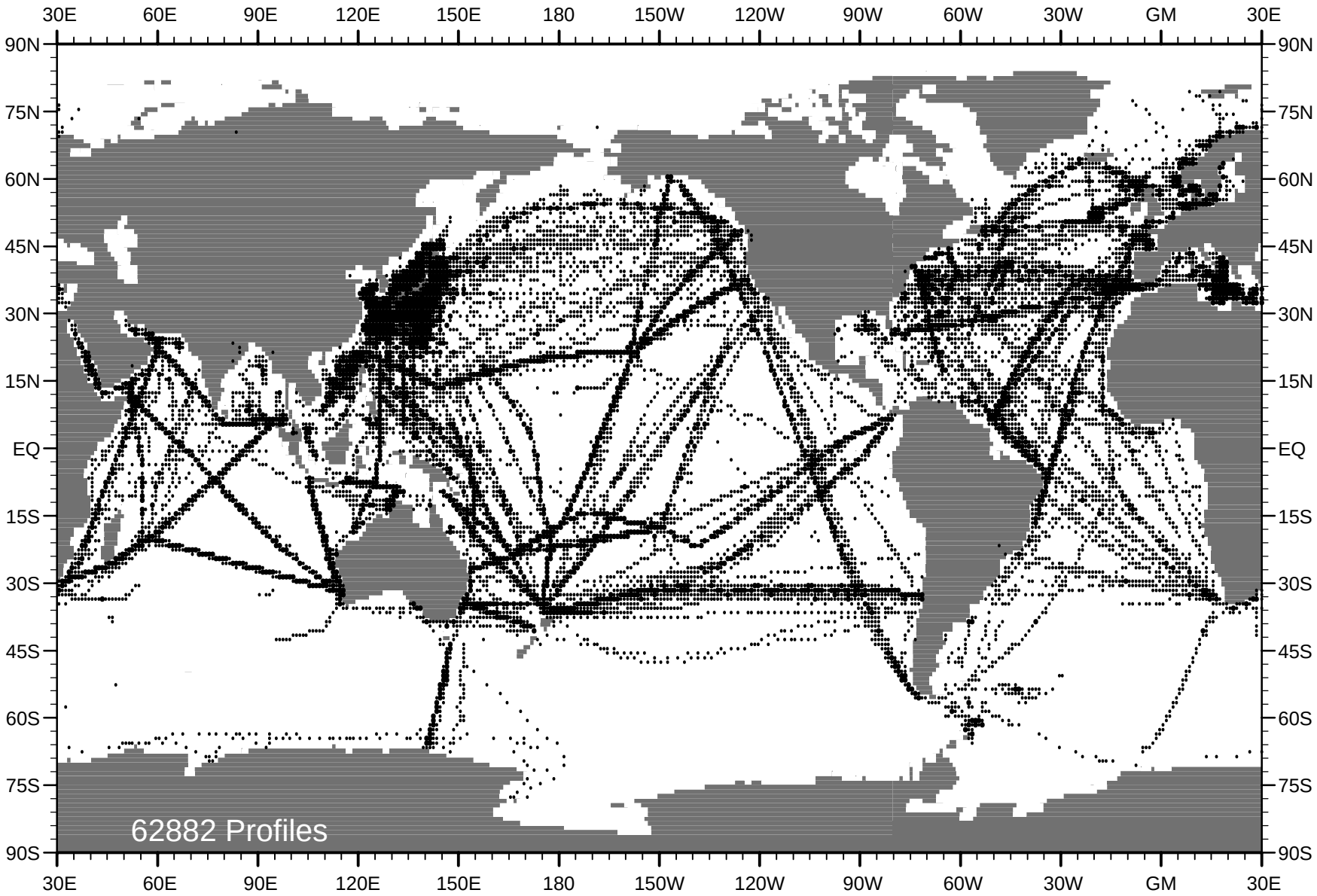

Fig. B30 WOD01 XBT profile distribution for year 1995 .

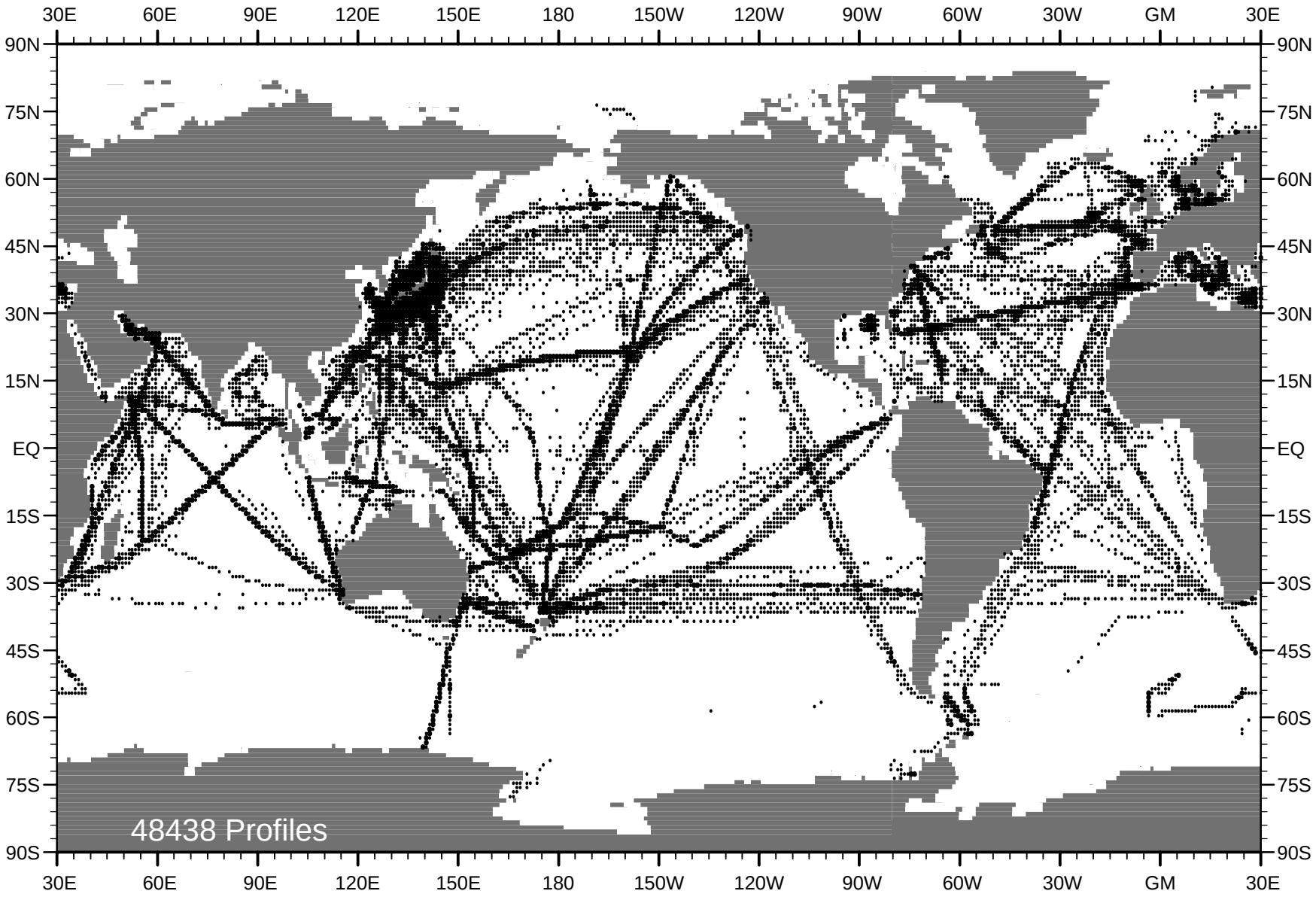

Fig. B31 WOD01 XBT profile distribution for year 1996 .

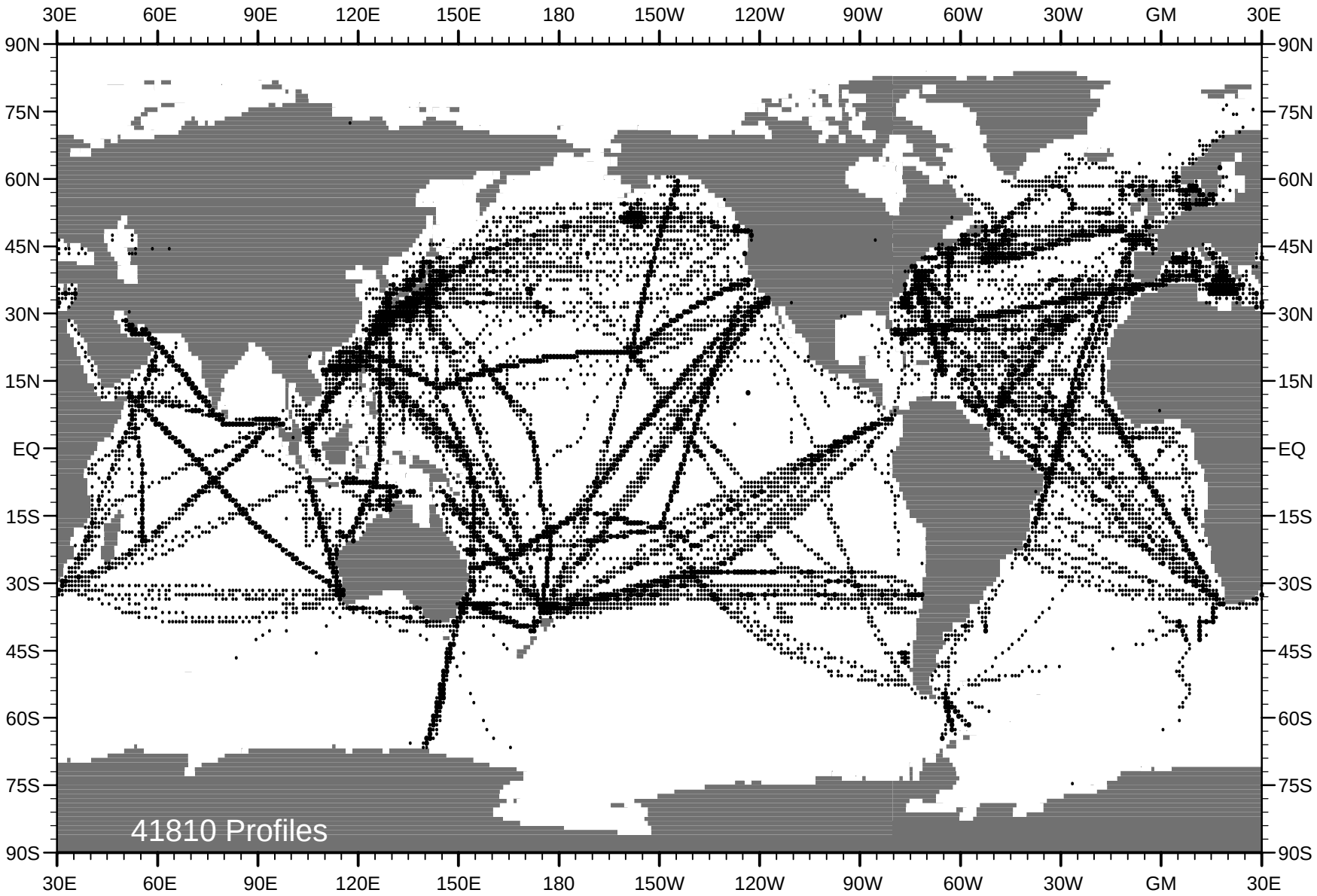

Fig. B32 WOD01 XBT profile distribution for year 1997 .

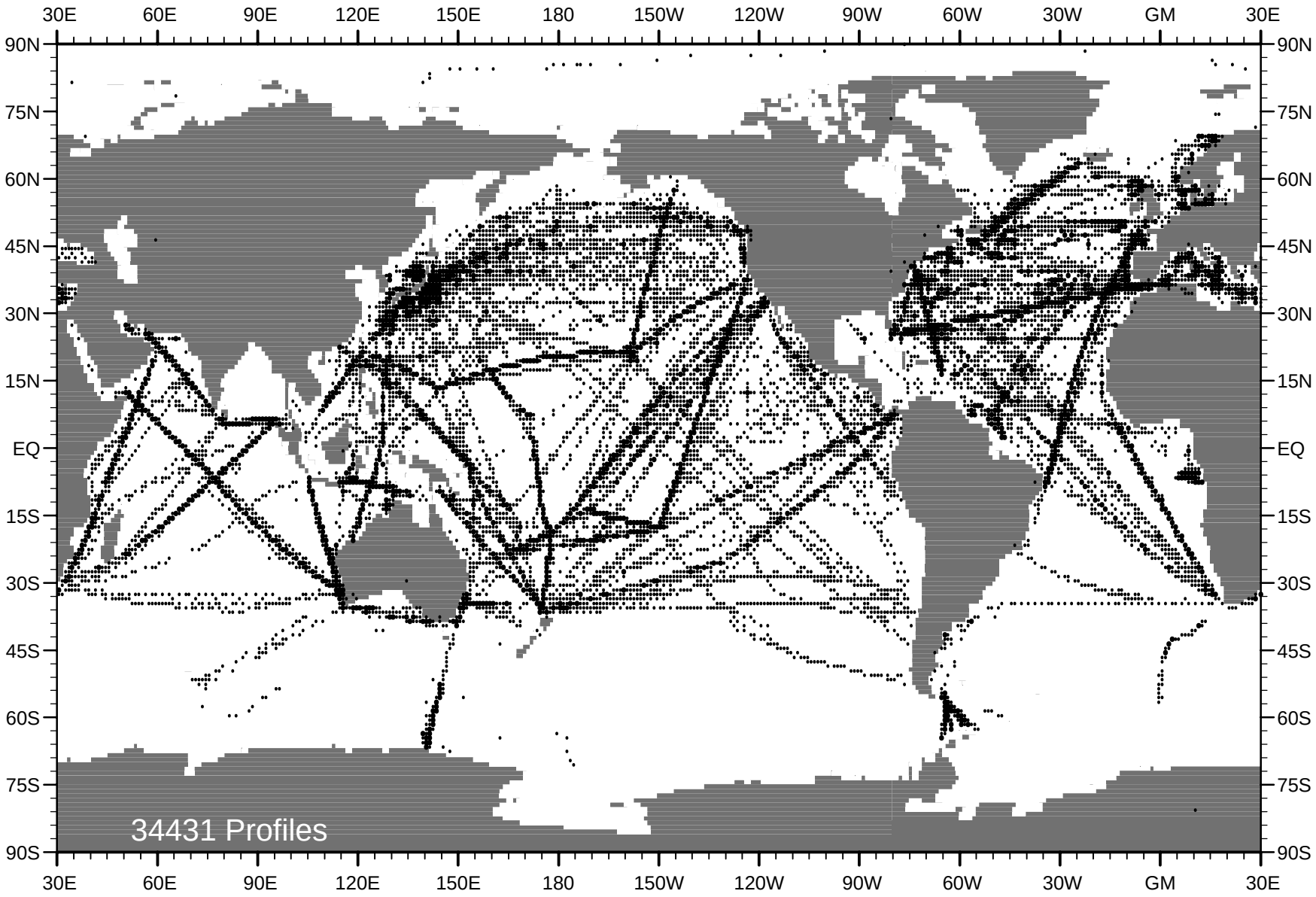

Fig. B33 WOD01 XBT profile distribution for year 1998 .

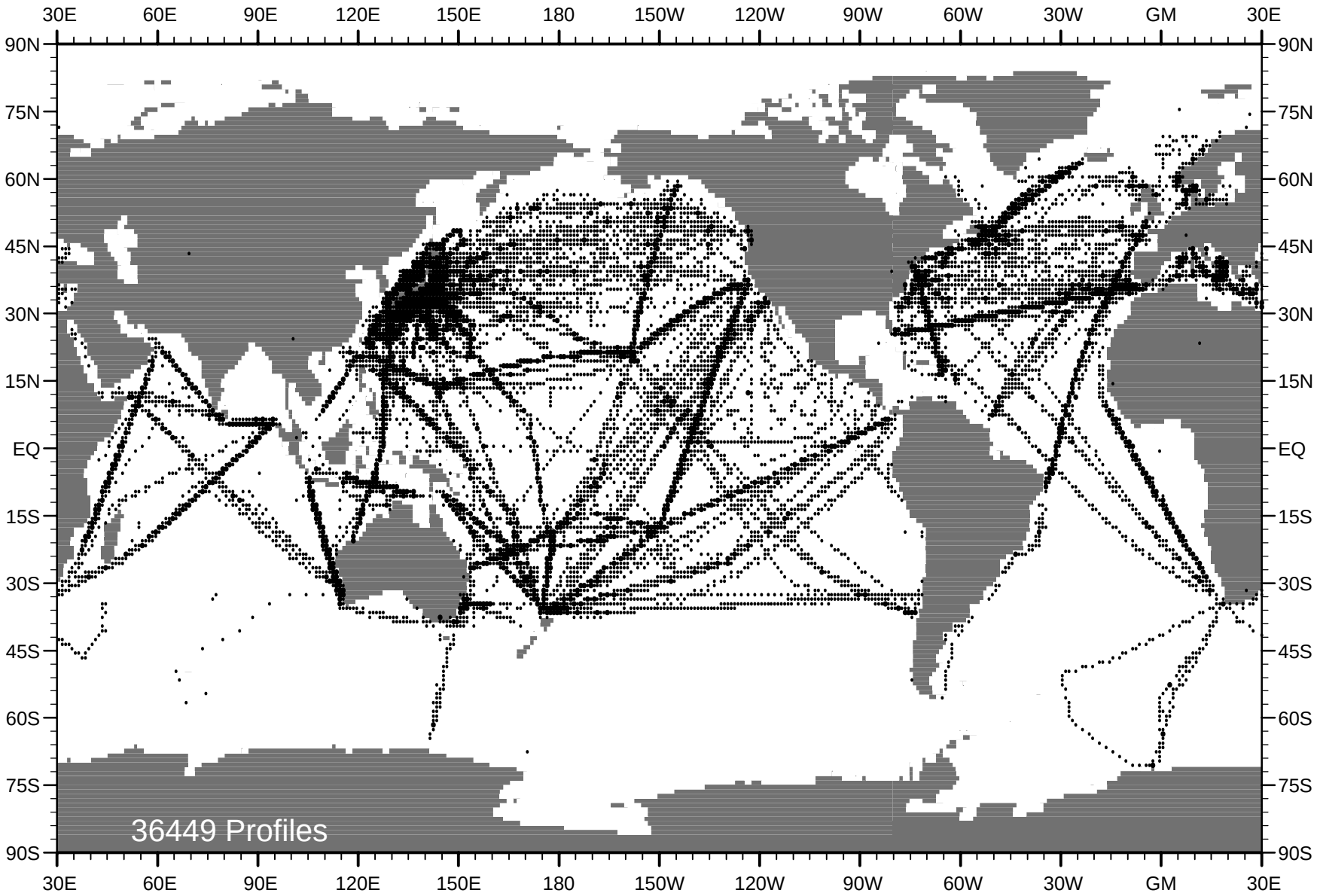

Fig. B34 WOD01 XBT profile distribution for year 1999 .

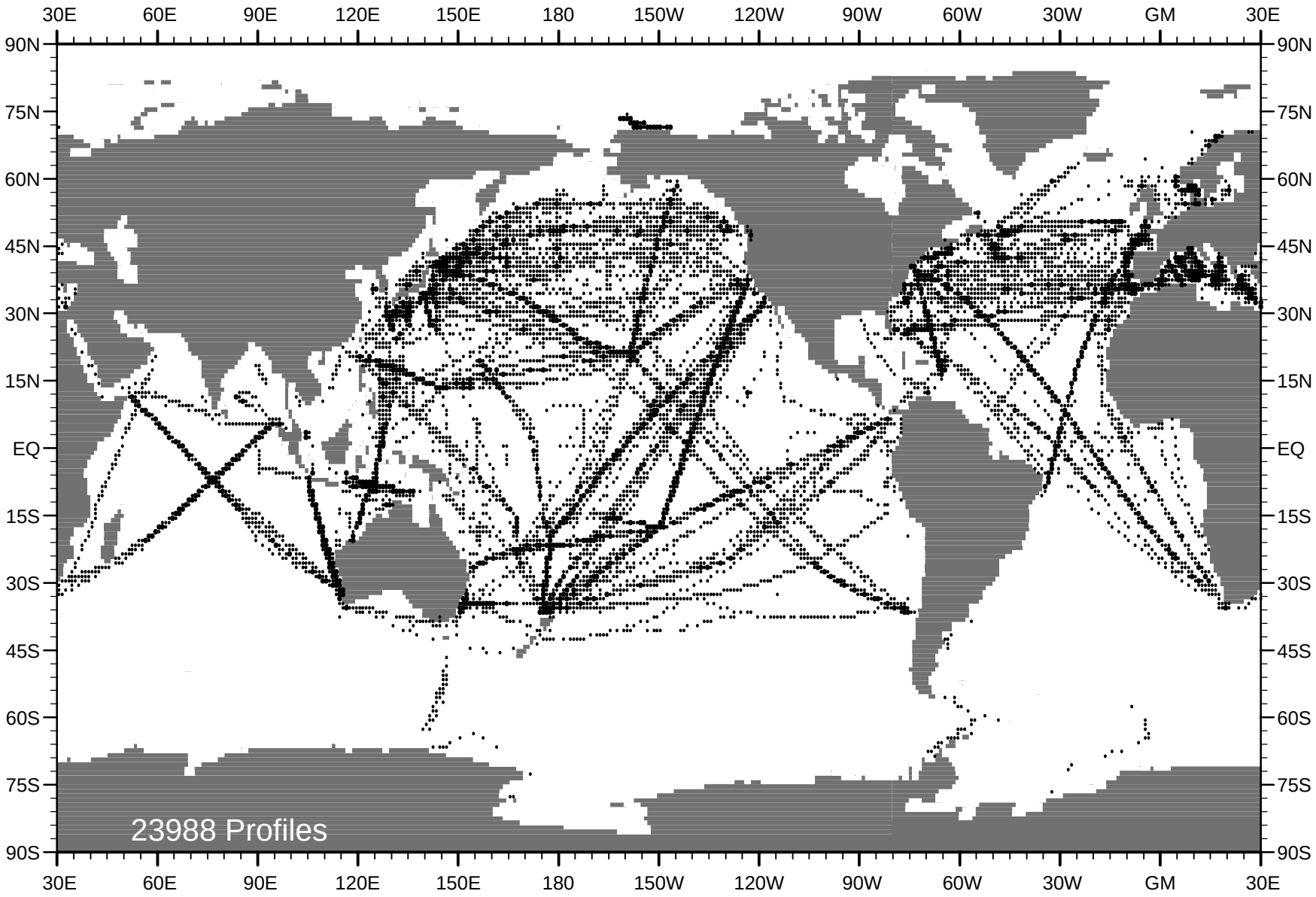

Fig. B35 WOD01 XBT profile distribution for year 2000 .

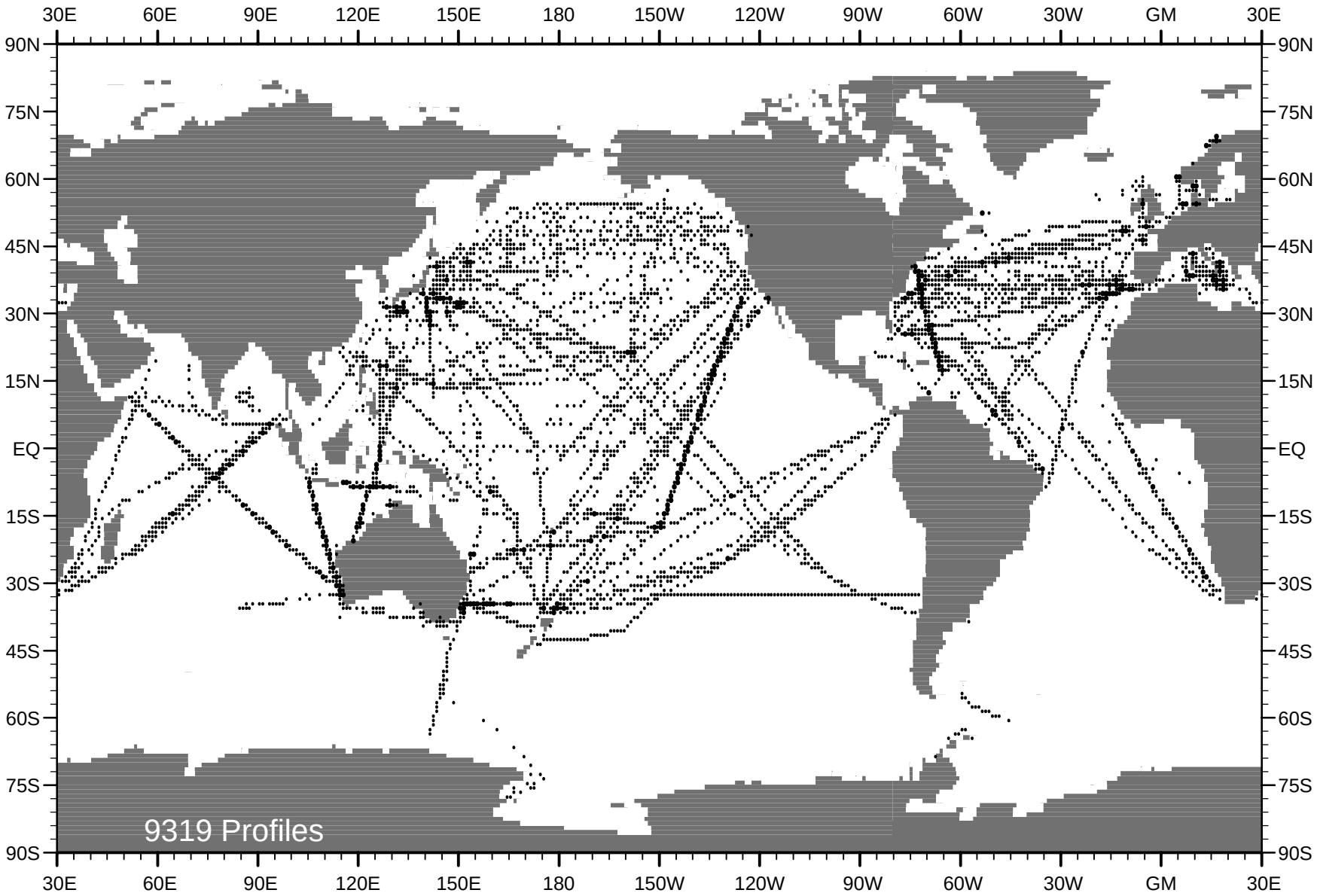

Fig. B36 WOD01 XBT profile distribution for year 2001 .