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QUALITY CONTROL AND PROCESSING OF HISTORICAL OCEANOGRAPHIC TEMPERATURE, SALINITY, AND OXYGEN DATA

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ABSTRACT

This paper describes the quality control procedures used to identify erroneous or nonrepresentative measurements in temperature, salinity, and oxygen databases used in the construction of climatological atlases (Levitus *et al*. 1994a,b,c,d). In conjunction with a similar paper dealing with phosphate, silicate, and nitrate (Conkright *et al.* 1994b), this paper intends to establish standard quality control of oceanographic data at the NODC Ocean Climate Laboratory.

1. INTRODUCTION

Oceanographers require high quality data in order to describe the temporal and spatial variability of physical, chemical and biological parameters in the oceans. The Ocean Climate Laboratory at the National Oceanographic Data Center (NODC) is supported by the NOAA Climate and Global Change program to produce scientifically quality controlled databases. A high quality database requires development of procedures which insure the integrity of the data.

Two major problems were encountered in the construction of our climatological atlases of objectively analyzed fields of oceanic data. The first was the paucity of data in many areas of the ocean. This problem can only be remedied by obtaining more data. The second was the use of data which do not appear to be representative of the actual parameter fields in an area of the ocean. These data, which will be henceforth termed "outliers", are nonrepresentative for a variety of reasons which can be categorized in three major groups:

1) problems with instrumentation

2) recording errors

3) sampled oceanographic features, such as eddies and fronts, which are nonrepresentative for the analyzed time and space scales.

The first category consisted mainly of problems with XBTs (expendable bathythermographs), such as the erroneous systematic drop rate formula associated with these instruments (IOC, 1992 a,b). Problems such as these were easily corrected when they came to light. Harder to identify and deal with were problems from the last two categories.

It may seem wrong at first glance to identify data in the third category as outlier data, but the purpose of the objective analysis was to produce a *climatic mean* field of oceanographic data. That is, a long-term average view of the ocean within the limits of available data. Relatively short term features, although detected by valid scientific measurements, can skew the overall mean of the parameter field. Therefore we do not wish to use measurements made in such features. All data considered for use in the atlases, however, were preserved and are available on magnetic media together with quality control flags that indicate whether or not particular data were excluded from the objective analysis and why. (Appendix B)

The system of quality control procedures used by Levitus (1982) has been improved upon and used to create the new climatologies (Levitus *et al*. 1994a,b,c,d; Conkright *et al*., 1994a). The quality control consisted of three major parts. First, all observed level data were examined. We define "observed level" data as data recorded at the actual depths of observations. Next, the data were interpolated to standard levels. The standard levels are thirty levels between the sea surface and 5000 m depth from the NODC standard level definition plus three additional deep ocean levels added by Levitus (1982) (3500 m, 4500 m, and 5500 m depth) (See Table 2 for a full list.). Interpolation to standard levels also represents a quality control step. Values at the standard levels were put through additional quality control checks, before and after initial objective analyses. The actual quality control steps used were:

Observed level data checks:

1) duplicate profile checks

2) depth duplication and inversion checks

3) individual basin data range checks

4) large temperature inversion and gradient checks

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5) interpolation to standard levels

Standard level data checks:

6) density inversion checks

7) standard deviation checks

8) post objective analysis subjective checks.

Each of these eight checks will be discussed in detail below. Please note that these quality control steps deal with both recording errors and nonrepresentative features, but do not directly address instrumentation problems. Instrumentation problems will be addressed separately.

2. DATA SOURCES AND DISTRIBUTIONS

Three different instrument groups were used to collect the data used in the analyses. These were: a) hydrographic casts (Station Data) which measure temperature through the use of reversing thermometers and capture of water samples with various bottle types at different depths for determination of salinity, oxygen, nutrients, etc.; b) CTDs (Conductivity/Temperature/Depth probes) and the related STDs (Salinity/Temperature/Depth probes); and c) bathythermographs of the mechanical (MBT), expendable (XBT), and digital (DBT) varieties. Of these three types, the hydrographic casts are the only data source prior to 1940. The bathythermographs are by far the most numerous measurement type for measuring subsurface temperature conditions in the world ocean. Table 1 lists all the sources of data by probe type which were incorporated into the data base used for the climatologies.

The Station Data and S/CTD data used in this project were obtained from the National Oceanographic Data Center (NODC), Washington, D.C. and represent all data available in the Oceanographic Station Data (SD) file and S/CTD file as of the first quarter of 1993 (NODC, 1993), plus data gathered as a result of the NODAR and GODAR projects (Levitus *et al*., 1994e) not yet archived in the NODC digital archives. In addition, the collection of international oceanographic profiles that comprise the Hydrographic Atlas of the Southern Ocean developed by Olbers *et al.* (1992) at the Alfred Wegener Institute for Polar and Marine Research were included as was the U.S. National Snow and Ice Data Center Eastern Arctic data set. Expendable bathythermograph (XBT) data and Mechanical Bathythermograph (MBT) data from the NODC files as of the third quarter of 1993 were used in our study. In addition, bathythermograph data gathered as a result of the NODC's National Oceanographic Data Archaeology and Rescue (NODAR) and the IODE/IOC Global Oceanographic Data Archaeology and Rescue (GODAR) projects were included in this work. A description of the NODAR and GODAR projects can be found in Levitus *et al.* (1994e).

Our data arrangement is slightly different than that used by NODC. In the past at NODC, some S/CTD data that were received at coarse vertical resolution were placed in the Station Data file. We have transferred these data to the S/CTD file. XBT and MBT data sent to NODC at non-standard levels are placed in the SBT (Selected Level Bathythermograph) file. We have transferred these data into the XBT and MBT files as appropriate. Thus, when using the XBT and MBT profile data sets we make available, it is important to know that one can not assume that all observed level XBT profile data are at inflection points, nor that all observed level MBT data are at 5 m intervals, as is the case for the NODC XBT and MBT archives.

3. QUALITY CONTROL

3.1 Instrumentation problems

A major instrumentation problem in the historical oceanographic data bases occurs in the XBT probe type. Estimates of the depth of measurements are dependent on the drop rate formulation. The original manufacturer's drop rate for certain XBT probes was found to contain a systematic error (Hanawa and Yoritaka, 1987: Hallock and Teague, 1992;, IOC, 1992a,b; Singer 1990). In general, T4, T6, and T7 probes fall faster than the calculated drop rate; the calculated depth of measurements are shallower than the actual depths. These XBT probe types were all found to have a depth error larger than the manufacturer's error margin of 2% plus or minus five meters (Hallock and Teague 1987). T5 probes were found to be within the error margin limits set by the manufacturer (Boyd and Lindsell 1992). Using a correction factor calculated by the IGOSS Task Team on Quality Control of Automated Systems (ITT/QCAS) (Szabados, personal communication), the observation depths of each XBT T4, T6, and T7 probe were adjusted before interpolation of data to standard level depths. These corrected data were used as input to the objective analysis of standard level temperature data. The equations used were:

$$\mathbf{z_c = 6.472t - 0.00216t^2} \qquad (1)$$

$$\mathbf{t = 1498.14 - (2244447.430 - 462.963\, z_0)^{1/2}} \qquad (2)$$

in which

z_c = corrected depth in meters
t = elapsed time since deployment of instrument
z_0 = originally calculated depth

Note that the observed level XBT profiles we make available on magnetic media and CD-ROM retain the originally received, uncorrected depths. Only the standard level data have incorporated the revised drop rate calculation.

Other problems, such as "bowing" (Wright, 1989; Bailey *et al.*, 1989) also occur in XBT measurements. Bowing is when the temperature profile of an XBT artificially arcs in areas of high temperature gradient due to resistance in the wire used. Corrections have not been made to the database for this problem.

3.2 Quality control of recording errors and nonrepresentative data

Identifying recording errors and nonrepresentative data (outliers) in all but the most obvious cases is a difficult task. In general, the validity of an observation is judged by comparison with accumulated knowledge about the area of the ocean from which the datum was taken. At the most basic level this means a data set is being judged against itself. To prepare the climatological atlases, a systematic approach to detect outliers was applied. In the next section we detail the four checks applied to observed level data, the method used to interpolate to standard level data, and the three checks applied to standard level data.

3.2a Duplicate profile check

We used data from many different sources in the course of our study. All data sets which we received were checked to determine if they contained replicate profiles. An exact replicate profile is one which contains the identical information as another profile, including position, date, as well as data values. Each profile in every newly received data set was then checked against all other profiles we possessed to determine if it was a replicate of any profile in existing data sets. Once all replicates were removed, the new data set was incorporated into our archive of data sets. The occurrence of replicate profiles is not rare, the reason being that the same data may be submitted to NODC or another data repository through more than one channel. The criteria for identifying replicates was by necessity very strict so as not to eliminate from use unique profiles. This being the case, two profiles which appear to be near duplicates may both have been saved, possibly because one source had interpolated the data to standard levels, while another source did not, or one source included minutes in the latitude and longitude while another source did not, *etc*. We identified approximately 25,700 exact replicates in the U.S. NODC Station Data file alone. Duplicates profiles were removed from our data set and are not included on the released data.

3.2b Depth inversion and depth duplication checks in individual profiles

Depth inversions and duplications of depths in a profile were found to occur in some profiles. A depth inversion occurs when an observation has a shallower depth than the observation directly preceding it. A depth duplication is a reading which has the same depth as the reading before it. In either case the second observation was always flagged and eliminated from use, rather than trying to judge the parameter data. If, after an inversion or duplication, the next depth observation was still shallower than the first reading, this observation and all subsequent observations were flagged and not used. This usually occurred when two or more profiles have been entered together into a digital file with no separating header information. In all, 10,202 profiles were flagged for having depth inversions or duplicate depths.

3.2c Range checks

For each of the ocean basins listed in Appendix A, Table 1, a set of depth dependent ranges was compiled. The basis for these ranges were the ranges set up for the entire ocean by Levitus (1982). These ranges were modified by searching the literature for each specific ocean area to identify typical and extreme parameter values for each ocean basin. But instead of ranges for each standard level for the entire ocean, as in Levitus (1982), we constructed depth dependent ranges for specific ocean areas. The ranges were further modified by testing them against the actual data; i.e. finding how many values fell outside the set ranges and the nature of these outside values. This was a subjective area of quality control. It should be noted that the ranges used are very broad and some areas are unchanged from the original work of Levitus (1982). This was due to lack of knowledge in certain areas as well as the great variability of data in some regions, coupled with the desire to err on the side of retaining erroneous data rather than flag possibly valid data. In addition, coastal areas of all oceans were given even larger ranges than the open ocean since extreme variability of parameters often occurs in these areas. A coastal area was defined as any one-degree grid box which was adjacent to a land grid box, or any one-degree grid box which had an average bottom depth of less than 200 meters.

The ranges are depth dependent and set for standard levels. However, the range checks were performed on observed level data, so a rough depth range criteria was needed to create a window of influence around each standard level. If an observation occurred at a depth within the window of a certain standard level, the parameter ranges set at that standard level were used to judge the validity of the parameter values. This window was created with a bias towards the deeper depth. No two windows overlapped. The window of a particular standard level extends upward 3/4 of the distance to the previous standard level, and down to 1/4 of the distance to the next standard level. For example, using standard level number 26, which has a depth of 2000 meters, the window for this depth stretches from 1815.5 meters (three fourths of the distance between level 26 and level 25 which is 1750 meters) and 2125 meters (one fourth of the distance between level 26 and level 27, which is 2500 meters). Any observed depth exactly on a border of two windows was governed by the ranges of the shallower depth.

The ranges for each ocean basin are found in Tables 2-4 in appendix A. Ranges were not set for the calculated parameters (Apparent Oxygen Utilization (AOU) and percent oxygen saturation).

3.2d Large temperature inversions and gradients

Relying solely on the temperature data which we possessed, we attempted to quantify what would be a maximum allowable temperature increase with depth (inversion) and a maximum allowable temperature decrease (excessive gradient) with depth. Beyond this, we assume that a recording error was involved, or a natural phenomena which was nonrepresentative occurred. Due to the great variability of data in the ocean, the criteria had to be set extremely large so that most of the resulting outliers appear to be gross recording errors. In these cases, this check was a valuable tool in finding outlier data. We assumed very large temperature inversions or excessive gradients were an indication of one or more of the involved values being an outlier, in particular when an inversion closely followed a large gradient or vice-versa. For inversions on observed levels, an outlier was assumed when there was an average increase of 0.3°C per meter between adjacent observations. A temperature decrease greater than $0.7°\mathrm{Cm}^{-1}$ was also deemed excessive. This method resulted in very few nonrepresentative feature outliers being flagged, but many recording errors were uncovered. Figure 1 is an example. It is easy to determine exactly what error occurred in recording or processing of this profile, but to manually find and correct all such errors was impractical in our large data bases. The gradient and inversion checks were valuable substitutes for profile by profile examination and correction. A further check used a combination of gradients and inversions. If a profile contained an inversion larger than the defined criteria, followed within a reasonable number of observations by an excessive gradient or vice versa, all values between (and including) the inversion and gradient were flagged. A reasonable distance was judged to be eight or fewer observations.

3.2e Vertical Interpolation method

The method used for vertical interpolation from observed readings to standard level values is important for quality control. A method must, as accurately as possible, interpolate data values from observed level readings to standard depth levels without creating spurious features. The method we used was a modified

Reiniger-Ross scheme (Reiniger and Ross, 1968). Reiniger-Ross, a widely used method (UNESCO, 1991) for interpolating oceanographic data, uses four observed values surrounding a standard level depth to which an interpolated value is to be calculated. From these four points, two above the standard level and two below, two three-point Lagrangian interpolations are computed. If the points are numbered 1 to 4, one being the shallowest point and four being the deepest point, the two Lagrangian interpolations are done for the sets (1,2,3) and (2,3,4). These two interpolated values are then averaged and fit to a reference curve as described by Reiniger and Ross (1968). This method creates fewer spurious extrema in regions of large vertical gradients than does a single three-point Lagrangian interpolation. When spurious extrema were created using the Reiniger-Ross scheme, another interpolation was used: if an interpolated value was not between the values of the two nearest observed readings, linear interpolation was substituted for the Reiniger-Ross interpolation.

Additionally, two maximum depth difference criteria were set for each standard level (Table 2). The first criterion established a maximum distance from the standard level to the adjacent shallower and deeper observed level observations. The second criterion limited the maximum distance to the shallowest and deepest observed level observations. This second set of maximum depth distances was much less strict than the first set, since the closer observed values have more influence on the interpolated value. If the outer maximum depth distance for interpolation to a standard level was violated, but not the inner distance, linear interpolation was substituted for Reiniger-Ross. If the inner distance criteria was violated, no standard level value was calculated.

If four points were not available to perform a Reiniger-Ross interpolation, such as at the end or beginning of a profile, a three-point Lagrangian interpolation (two above, one below or; one above, two below) was performed. If the first reading in a profile was at or above five meters depth, this first reading was used directly for the first (surface) standard level. If Lagrangian interpolation was not possible, linear interpolation was performed. This occurred mainly when, as noted above, the outer maximum depth criteria was violated, when the additional check (also mentioned above) was violated, or finally, when there were only two surrounding values in a profile. If an observed value was taken directly at a standard depth, direct substitution was used. Figure 2 is an example of the interpolation method, showing observed and standard levels for a temperature profile.

In the case of the calculated parameters, Apparent Oxygen Utilization and oxygen saturation, values were calculated on observed levels using all unflagged temperature, salinity, and oxygen triplets. AOU was calculated using the Garcia-Gordon (1992) formula and percent oxygen saturation was calculated using the AOU value as a percent of total saturation. These calculated values were then interpolated to standard levels using the above method.

Any parameter values which were flagged in an observed level check, and all parameter values associated with a flagged depth level, were not used to calculate standard level values.

3.2f Standard level density check

The standard level density check was the same as that used by Levitus (1982). Each profile was checked for static stability using Hesselberg and Sverdrup's (1914) definition. The computation is a local one in the sense that adiabatic displacements between adjacent temperature-salinity measurements in the vertical are considered rather than displacements to the seas surface. The procedure for stability (E) computation follows that used by Lynn and Reid (1968):

$$E = \lim_{\partial z \to 0} \frac{1}{\rho_0} \frac{\rho}{\partial z}$$

where ρ_0 = 1.02 g/cm^3 and z is depth in meters. As noted by Lynn and Reid the term is "the individual gradient defined by vertical displacement of a water parcel". For discrete samples, the density difference (ρ) between two samples is taken after the deeper sample is adiabatically displaced to the standard level of the shallower sample. ρ is then simply the displaced sample's density minus the shallower sample's density. Densities were calculated using the IGOSS standard density equation (1993) on interpolated temperature and salinity data. An inversion was defined as anywhere that ρ was less than zero. For observations with a deeper sample depth of 30 meters or less, an inversion of $3x10^{-5}$ g/cm^3 was considered an indication of a problem with the data. The temperature and salinity at both of these depths were flagged and eliminated from use in the analysis. For observations with a deeper sample depth between 50 and 400 meters an inversion of $2x10^{-5}$ g/cm^3 was considered excessive. For depths greater than 400 meters any inversion greater than 10^{-6} g/cm^3 was considered excessive. If two or more such density inversions were found in one profile, all temperature and salinity values were flagged as unusable for this profile.

3.2g Standard deviation check

An important check in discarding nonrepresentative values was the "standard deviation" check. In this check, the world was divided into five-degree latitude by five-degree longitude boxes. Each of these boxes was designated coastal, near coastal or open ocean, based on the number of one-degree by one-degree latitude-longitude gridboxes in the five-degree box which were land (0 m depth) areas. Means and standard deviations were calculated for each five-degree box. Next, each profile in the five-degree grid box was checked against these statistics: If a value at any standard depth of the profile exceeded [N (standard deviations)] it was flagged and not used in the objective analysis. N is a number dependent on the five-degree box designation, the depth of the standard level being examined and the average depth of the ocean in the one-degree grid box and surrounding one-degree boxes. For the first five standard depths (0 to 50m), a value of N=3 was assigned to open ocean grid boxes N=4 for near coastal grid boxes, and N=5 for coastal grid boxes. Below the fifth standard depth [50 m], N=3 was assigned, except when a profile was at or below the average depth level for the one-degree box in which it was contained or any of the adjacent one degree boxes, in such cases we set N=4. N is greater near the coast to permit the high variability of parameters due to river runoff, upwelling and other factors. Also variability within a five-degree box near the ocean bottom can occur because the five-degree box contains the boundary of two basins: i.e. the mid-Atlantic ridge separating east and west Atlantic waters. This check was only performed if there were five or more profiles in the five-degree grid box. In addition to discarding individual readings, an entire profile was deemed unusable if the profile contained two or more levels which failed the standard deviation check.

After the standard deviation check, means and standard deviations were recalculated, excluding individual values and profiles which failed the check. The procedure was then repeated a third time. In all, the mean and standard deviation were calculated three times for the five-degree grid boxes, each time with tighter criteria. At the end of the third calculation, the one-degree grid box means were calculated excluding all flagged standard level data. Data associated with density inversions, standard deviation outliers were omitted. Profiles and levels flagged in post-analysis checks (described below) were also omitted from use in calculating the means. The one-degree means were the input for the final objective analysis.

Oxygen content, AOU, and percent oxygen saturation were run through the standard deviation check separately, so the final input to the objective analysis of these profiles consisted of slightly different numbers of profiles than oxygen. Similarly, for salinity, temperature, and oxygen (and it's calculated parameters), total and seasonal standard deviation checks were run separately with slightly different results. For example, a temperature observation taken in winter may be well within the standard deviation of only winter values, but outside the acceptable limit using all profiles, or vice-versa.

3.2h Post objective analysis checks

After the initial objective analysis additional subjective checks were required. Contour maps of the world ocean parameter fields occasionally contained unrealistic features such as bullseyes, mostly in data sparse areas such as the Southern Ocean. In data sparse areas it was difficult to detect all nonrepresentative data with our automated checks. To eliminate these bullseyes, all the data in an area were subjectively examined to try to find the anomalous observations. When any suspicious data were found they were eliminated from use, and the input field for the objective analysis was recomputed. In some cases, entire cruises were eliminated because a cruise was creating outliers wherever it took profiles. In one case, with oxygen data, all cruises for one country (Brazil) were eliminated.

These checks were implemented as sparingly as possible. In general we chose to err on the side of retaining representative or erroneous data in our analysis rather than chance eliminating good data. Hence there are still outliers and what appear to be anomalous highs and lows in the contour maps. These problems are unavoidable given the amount of data available in some ocean areas.

Oxygen values causing bullseyes in annual AOU, percent oxygen saturation, and/or oxygen content analyses were eliminated from use in calculating means as input for all three parameters since all three parameters are related. Salinity, temperature, or oxygen values found to create bullseyes in seasonal analyses were eliminated from use in compiling statistics for annual analyses and vice-versa. This principle extended to monthly analyses for temperature.

4. RESULTS

The results of the quality control process can best be judged by the figures in the atlases (Levitus *et al.* 1994a,b,c,d and Conkright *et al.* 1994a). Some insight to the areas needing future study can be gained by examining statistical results of each individual step. Table 3 lists the data values flagged on observed levels for temperature, salinity, and oxygen. The percentage of profiles with flagged values is barely above one percent for any parameter. Further study of the ranges of parameter values found in individual ocean basins, and the inclusion of seasonal ranges will help to identify other outlier data. Note that the temperature inversion and excessive gradient checks found numerous outliers (more than 25,000) in the Wood's Hole MBT data set, uncovering what may be a systematic computer processing error in a portion of this archive. This data set was digitized during the 1970's but never distributed. Profiles that have the most "errors" are being digitized. In addition we have found that some of the original profiles were never digitized. These also are being digitized.

Tables 4a through 4e show the results of interpolation from observed to standard levels. Well over half of all temperature and salinity values were substituted directly from observed to standard levels. For oxygen and its calculated parameters, the number of direct substitutions was somewhat less than one half of all values. For all parameters, the Reiniger-Ross method was the second most frequently used method of interpolating data to standard levels.

Tables 5a-5e show the results of standard level quality control checks. From tables 5a-5d it can be seen that the largest number of flagged standard level profiles and values came from the density inversion check. This is most evident when looking at 5c and 5d, the results of the salinity checks. We speculate that the large number of flagged profiles indicates the possibility that the criteria used is too restrictive, and there are actually relatively large density inversions occurring in the world ocean. Further study is needed to answer these questions. The statistics do not show a large seasonal bias to any of the quality control checks, with the possible exception of winter salinity flags.

All the cruises flagged as part of the post objective analysis checks are listed in tables 6a-6c. Figures 7a-7d show the number of acceptable data values at each standard depth that actually went into the final objective analyses. The number of data values decreases rapidly with depth for all parameters. For temperature, a very large decrease occurs after 400 meters. This is because the most widely used XBT is the T4 probe which has a maximum penetration depth of 450 meters.

5. SUMMARY AND FUTURE WORK

Quality control of ocean physical parameters is a vital step towards providing increased understanding of the oceans. In setting up systematic, documented procedures for determining the quality of incoming data at the Ocean Climate Laboratory, we hope to be able to improve the state of historical ocean data bases so they can be used with understanding and confidence.

Despite the fact that a system has been set up for quality control, much needs to be done in order to operate it with total confidence. Feedback from the scientific community will greatly aid us in improving the quality control. Future work in this area will include setting up ranges by season for each basin, as well as improving the ranges already in place. Studying density inversions in the historical data to better understand this condition is also necessary.

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Figure 1: Profile with extra large gradient followed by a large temperature inversion (measurements in question marked with an "x").

Longitude	Latitude	Year	Month	Day
132.22	33.07	1972	9	7

	Depth	Temperature
1.	0.0	24.10
2.	4.0	23.80x
3.	8.0	2.38x
4.	15.0	23.60x
5.	23.0	23.60
6.	38.0	23.60

Figure 2: Example of interpolation to standard levels

Longitude	Latitude	Year	Month	Day
-10.14	54.25	1905	5	19

	Observed Depth	Temperature	Standard Depth	Temperature (interpolated)
1.	0.0	11.60	0.0	11.60
2.	2.0	11.60		
3.	9.0	10.90		
			10.0	10.81
4.	18.0	10.20		
			20.0	10.08
			30.0	9.64
5.	37.0	9.50		
			50.0	9.41
6.	55.0	9.40		
7.	73.0	9.40		
			75.0	9.40
8.	91.0	9.40		
			100.0	9.38
9.	117.0	9.30		

Table 1: Sources of Data used in the Objective Analyses

Station Data	Number of Profiles
United States NODC (National Oceanographic Data Center)	804,357
Japanese Oceanographic Data Center	254,846
Korean NODC	28,194
Alfred Wegner Institute for Polar Studies Southern Ocean Data Set	25,599
Combined Mediterranean Data Set	24,026
Australian NODC	22,190
Russia	11,560
Iceland	7,323
International Council for the Exploration of the Seas (ICES)	6,329
Pacific Oceanological Institute (Russia) South China Sea Data Set	5,543
Germany	2,505
Miscellaneous ships of opportunity	1,172
Indian NODC	650
Scripps Institute of Oceanography Southtow Cruises	113
Total	1,194,407

CTD/STD	Number of Profiles
United States NODC	132,614
U.S. National Snow and Ice Data Center Eastern Arctic Data Set	4,530
Pacific Oceanological Institute	4,249
Barents Sea Data Set (Russia)	2,013
Scripps Institute of Oceanography Southtow Cruises	49
Total	143,455

Mechanical Bathythermograph (MBT)	Number of Profiles
United States NODC	1,154,181
Russia	241,217
Woods Hole Oceanographic Institute	203,840
Canada (MEDS)	145,286
Miscellaneous ships of opportunity	73,987
Japanese Fisheries	60,764
France	2,791
Argentina	376
Total	1,912,170

Expendable Bathythermographs (XBT)	Number of Profiles
United States NODC	970,332
Global Temperature and Salinity Pilot Project (GTSPP) real time data	146,603
United States Navy Declassified Data	99,532
Canada (MEDS)	46,658
GTSPP delayed mode data	17,120
Great Britain	1,697
Total	1,281,942

Digital Bathythermographs (DBT)	Number of Profiles
Japanese Fisheries	23,452
Canada (MEDS)	11,563
Total	35,015
TOTAL PROFILES	4,566,989

Table 2. Acceptable distances for "inside" and "outside" values used in the Reiniger-Ross scheme for interpolating observed level data to standard levels

Standard Levels	Standard Depths	Acceptable distances for inside values	Acceptable distances for outside values
1	0	5	200
2	10	50	200
3	20	50	200
4	30	50	200
5	50	50	200
6	75	50	200
7	100	50	200
8	125	50	200
9	150	50	200
10	200	50	200
11	250	100	200
12	300	100	200
13	400	100	200
14	500	100	400
15	600	100	400
16	700	100	400
17	800	100	400
18	900	200	400
19	1000	200	400
20	1100	200	400
21	1200	200	400
22	1300	200	1000
23	1400	200	1000
24	1500	200	1000
25	1750	200	1000
26	2000	1000	1000
27	2500	1000	1000
28	3000	1000	1000
29	3500	1000	1000
30	4000	1000	1000
31	4500	1000	1000
32	5000	1000	1000
33	5500	1000	1000

Table 3 Observed level profiles containing quality control flags

Flag Type	Temperature	Salinity	Oxygen
Measurement Outside Set Ranges	35,548	13,137	4,789
Excessive Inversion	17,773	NA	NA
Excessive Vertical Gradient	10,875	NA	NA
Combination of Temperature Gradient and Inversion	3,563	NA	NA
Total Number of Profiles Containing Flags	48,403	13,137	4,789
Total Number of Profiles	4,563,606	1,262,723	371,635
Percent of Observed Level Profiles Containing Flags	1.1%	1.0%	1.3%

NA - Not Applicable

Table 4a. Information on interpolation from observed levels to standard levels for temperature data

Number of Observed Level Temperature Profiles	4,563,606
Number of Standard Level Temperature Profiles	4,553,426
Observed Level Measurements	103,541,371
Total data points at Standard Levels	41,168,483

Interpolation Method	Number of Standard Levels Filled Using Method	% of standard levels
Direct Substitution from Observed Measurement	22,851,930	55.5%
Interpolated Using Reiniger-Ross Method	13,512,117	32.8%
Interpolated Using Three Point Lagrangian Method	1,820,868	4.4%
Linear Interpolation	2,983,568	7.3%

Table 4b. Information on interpolation from observed levels to standard levels for salinity temperature data

Number of Observed Level Salinity Profiles	1,262,723
Number of Standard Level Salinity Profiles	1,254,771
Observed Level Measurements	14,588,412
Total data points at Standard Levels	11,209,372

Interpolation Method	Number of Standard Levels Filled Using Method	% of standard levels
Direct Substitution from Observed Measurement	6,160,080	54.9%
Interpolated Using Reiniger-Ross Method	3,474,075	31.0%
Interpolated Using Three Point Lagrangian Method	782,454	7.0%
Linear Interpolation	792,763	7.1%

Table 4c. Information on interpolation from observed levels to standard levels for oxygen data

Number of Observed Level Oxygen Profiles	371,813
Number of Standard Level Oxygen Profiles	367,635
Observed Level Measurements	4,167,465
Total data points at Standard Levels	3,904,939

Interpolation Method	Number of Standard Levels Filled Using Method	% of standard levels
Direct Substitution from Observed Measurement	1,676,232	42.9%
Interpolated Using Reiniger-Ross Method	1,533,911	39.3%
Interpolated Using Three Point Lagrangian Method	348,724	8.9%
Linear Interpolation	346,072	8.9%

Table 4d. Information on interpolation from observed levels to standard levels for Apparent Oxygen Utilization (AOU) data

Number of Observed Level AOU Profiles	365,816
Number of Standard Level AOU Profiles	365,689
Observed Level Measurements	4,021,985
Total data points at Standard Levels	3,784,315

Interpolation Method	Number of Standard Levels Filled Using Method	% of standard levels
Direct Substitution from Observed Measurement	1,637,613	43.3%
Interpolated Using Reiniger-Ross Method	1,499,979	39.6%
Interpolated Using Three Point Lagrangian Method	346,397	9.2%
Linear Interpolation	300,326	7.9%

Table 4e. Information on interpolation from observed levels to standard levels for percent oxygen saturation data

Number of Observed Level % O2 Saturation Profiles	365,816
Number of Standard Level % O2 Saturation Profiles	365,689
Observed Level Measurements	4,021,985
Total data points at Standard Levels	3,784,315

Interpolation Method	Number of Standard Levels Filled Using Method	% of standard levels
Direct Substitution from Observed Measurement	1,637,613	43.3%
Interpolated Using Reiniger-Ross Method	1,493,428	39.4%
Interpolated Using Three Point Lagrangian Method	345,067	9.2%
Linear Interpolation	308,207	8.1%

Table 5a. Standard level temperature profiles not used due to quality control checks

Reason for Non-Use	Annual	Winter	Spring	Summer	Fall
Two or More Density Inversions	58,896	19,118	12,133	9,562	18,083
Two or More Values Exceed Standard Deviation Criteria	62,587	13,531	17,070	22,574	15,686
Cruise not used	374	0	337	37	0
Profile Creates Bullseye	471	124	37	136	174
Total Unused Whole Profiles	122,328	32,773	29,577	32,309	33,943
Total Profiles	4,553,461	997,502	1,244,178	1,313,690	998,091
% Whole Profiles Not Used	2.7%	3.3%	2.4%	2.5%	3.4%

Table 5b. Standard level temperature profiles with at least one level flagged
(excluding profiles not used due to quality control checks, as in 5a)

Type of Flag	Annual	Winter	Spring	Summer	Fall
Density Inversion	166,719	42,046	38,898	38,211	47,564
Exceeds Standard Deviation Criteria	48,702	12,133	12,541	14,985	10,815
One Level Bullseye Flag	91	19	18	19	34
Total Profiles with Flagged Levels	215,512	34,198	51,457	53,215	58,413
Total Profiles	4,553,461	997,502	1,244,178	1,313,690	998,091
% Profiles with Flagged levels	4.7%	5.4%	4.1%	4.0%	5.9%

Table 5c. Standard level salinity profiles not used due to quality control checks

Reason for Non-Use	Annual	Winter	Spring	Summer	Fall
Two or More Density Inversions	58,896	19,118	12,133	9,562	18,083
Two or MoreValues Exceed Standard Deviation Criteria	16,559	2,717	3,618	3,804	2,033
Cruise Not Used	5,233	2,664	873	1,169	527
Profile Creates Bullseye	29	2	3	7	17
Total Unused Whole Profiles	80,717	24,501	16,627	14,542	20,660
Total Profiles	1,251,925	267,199	349,763	373,400	261,563
% Whole Profiles Not Used	6.4%	9.1%	4.8%	3.9%	7.9%

Table 5d. Standard level salinity profiles with at least one level flagged
(excluding profiles not used due to quality control checks, as in 5c)

Type of Flag	Annual	Winter	Spring	Summer	Fall
Density Inversion	166,719	42,046	38,898	38,211	47,564
Exceeds Standard Deviation Criteria	21,356	3,986	5,566	6,078	3,538
One Level Bullseye Flag	1,086	559	448	531	548
Total Profiles With Flagged Levels	189,161	46,591	44,912	44,820	51,650
Total Profiles	1,251,925	267,199	349,763	373,400	261,563
% Profiles with Flagged levels	15.1%	17.4%	12.8%	12.0%	19.7%

Table 5e. Standard level oxygen profiles not used due to quality control checks

Reason for Non-Use	Annual	Winter	Spring	Summer	Fall
Two or More Values Exceed Standard Deviation Criteria	9,222	1,380	1,338	1,430	829
Data from Country Not Used	5,827	1,076	1,493	1,496	1,762
Cruise Not Used	1,091	470	116	145	360
Profile Creates Bullseye	159	49	35	50	25
Total Unused Whole Profiles	16,299	2,975	3,082	3,121	2,976
Total Profiles	367,635	88,410	98,339	105,666	75,220
% Whole Profiles Not Used	4.4%	3.4%	3.1%	2.9%	4.0%

Table 5f. Standard level oxygen profiles with at least one level flagged
(excluding profiles not used due to quality control checks, as in 5e)

Type of Flag	Annual	Winter	Spring	Summer	Fall
Exceeds Standard Deviation Criteria	7,515	1,851	1,820	2,255	1,299
One Level Bullseye Flag	200	56	44	68	32
Total Profiles with Flagged Levels	7,715	1,907	1,864	2,323	1,331
Total Profiles	367,635	88,410	98,339	105,666	75,220
% Profiles with Flagged levels	2.1	2.2	1.9	2.2	1.8

Table 6a. Cruises flagged for temperature

NODC Cruise#	Country	Probe Type	Date	Location	Profiles
7399	U.S.	MBT	May-Jul 1963	Eq. Indian	293. S
52747	Australia	XBT	May-Jul 1977	South Indian	81

Table 6b. Cruises flagged for salinity

NODC Cruise#	Country	Probe Type	Date	Location	Profiles
30	New Zealand	hydrocast	Nov-Dec 1958	South Pacific	24
990	Spain	hydrocast	August 1963	Eq. Atlantic	45
1	Ecuador	hydrocast	Feb-Jun 1964	Eq. Pacific	142
7069	Russia	hydrocast	Dec 1968-Mar 1969	South Pacific	70
1481	Japan	hydrocast	Mar-Dec 1969	Eq. Pacific	40
9010	U.S.	CTD	Jun-Jul 1968	North Atlantic	76
369	Russia	hydrocast	Sep-Oct 1970	North Pacific	47
7090	Russia	hydrocast	December 1979	North Pacific	40
7166	Russia	hydrocast	Aug-Sep 1981	North Pacific-North Atlantic	84
7164	Russia	hydrocast	Dec 1982-Jan 1983	South Atlantic	114
7146	Russia	hydrocast	Apr-Jun 1984	North Atlantic	218
7142	Russia	hydrocast	Oct-Nov 1984	North Atlantic	295
7149	Russia	hydrocast	Dec 1984-Jan 1985	North Atlantic	247

Table 6c. Cruises flagged for oxygen

NODC Cruise#	Country	Probe Type	Date	Location	Profiles
5	U.K.	hydrocast	Sep 1933-May 1934	North Pacific	99
501	U.S.	hydrocast	Mar-Apr 1955	North Pacific	22.W
573	Canada	hydrocast	Jul-Sep 1957	North Atlantic	79
497	Canada	hydrocast	Nov 1961-Jul 1962	Arctic	15
150	U.S.	hydrocast	Feb-Mar 1963	Antarctic	99
180	U.S.	hydrocast	Aug-Sep 1963	North Pacific	22
1479	Canada	hydrocast	April 1967	Arctic	25
1302	Thailand	hydrocast	Nov-Dec 1967	North Indian	121
1621	U.S.	hydrocast	Jan-Nov 1968	North Pacific	67.U
1306	Thailand	hydrocast	February 1968	Eq. Indian	89
1145	Russia	hydrocast	September 1971	South Atlantic	8
8517	U.S.	hydrocast	Aug-Sep 1972	Eq. Indian	6
35	France	hydrocast	Apr-Jun 1975	North Pacific	26
3000	U.S.	hydrocast	May-Jun 1976	North Pacific	36
8493	Japan	hydrocast	Nov 1979-Mar 1980	Red Sea-North Indian	14
7137	Russia	hydrocast	Nov-Dec 1982	North Pacific	55
7135	Russia	hydrocast	Dec 1983-Feb 1984	North Atlantic	314
ALL	Brazil	hydrocast	-------	-------	5827.*

.W- Only Winter profiles flagged for cruise
.S - Only Spring profiles flagged from cruise
.U - Only Summer profiles flagged cruise
.* - the first 33 oxygen profiles in the US NODC station data file were inadvertently added to the profiles which were excluded from Brazilian cruises. Though unfortunate, these 33 profiles all occur in the far north of the Baltic Sea and have little effect on the analysis outside this region. The actual number of Brazilian oxygen profiles at NODC is 5794.

Table 7a. Number of Unflagged Standard Level Temperature Values per Depth Level

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
0	4,296,992	932,694	1,180,061	1,245,186	931,441
10	3,988,282	814,529	1,117,659	1,202,379	845,871
20	3,998,430	820,630	1,113,645	1,195,421	861,049
30	3,930,411	811,296	1,093,595	1,165,189	853,143
50	3,600,380	739,738	1,011,438	1,072,039	770,710
75	3,315,824	688,755	926,047	969,223	725,863
100	3,100,158	664,703	853,154	888,685	688,676
125	2,763,258	610,799	751,717	781,757	615,294
150	2,359,551	536,383	640,014	655,301	525,943
200	2,030,530	470,101	550,900	559,925	448,059
250	1,818,921	427,423	490,091	497,659	402,178
300	1,310,635	314,526	352,650	350,908	291,248
400	1,143,762	277,669	305,079	302,499	257,200
500	472,393	116,739	130,640	125,475	99,476
600	277,325	68,069	78,314	72,973	58,212
700	230,516	58,007	66,438	56,975	49,313
800	121,386	31,138	36,317	30,879	23,241
900	183,491	45,158	53,221	51,638	33,651
1000	150,614	36,919	43,752	42,598	27,465
1100	115,086	29,542	32,438	31,854	21,368
1200	81,185	21,019	22,943	22,103	15,186
1300	69,411	19,050	19,757	18,300	12,453
1400	59,231	16,796	16,441	15,287	10,768
1500	41,752	11,994	12,060	10,695	7,051
1750	18,596	6,629	4,946	3,912	3,140

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
2000	56,231	16,019	15,355	14,922	10,436
2500	30,869	9,174	8,381	8,091	5,215
3000	23,271	6,887	6,483	6,068	3,844
3500	18,032	5,343	5,104	4,657	2,934
4000	13,490	3,963	3,930	3,521	2,088
4500	8,800	2,477	2,724	2,303	1,311
5000	5,153	1,526	1,527	1,379	724
5500	2,753	917	718	803	312
Total profiles with at least one level	4,430,774	964,225	1,214,397	1,281,143	963,716

Table 7b. Number of Unflagged Standard Level Salinity Values per Depth Level

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
0	1,034,091	211,365	301,584	323,629	199,712
10	973,600	196,777	286,981	307,871	183,798
20	981,729	202,244	282,450	305,507	193,443
30	926,511	191,051	266,101	288,583	182,704
50	829,881	171,580	241,863	255,461	162,861
75	704,756	147,891	206,023	215,550	137,366
100	625,189	132,960	183,385	190,613	120,123
125	544,416	118,618	157,834	165,420	104,226
150	514,346	111,916	149,825	156,844	97,431
200	397,916	89,124	115,847	119,638	74,716
250	424,439	94,555	122,219	129,111	80,003
300	371,042	84,283	106,932	112,133	69,145
400	275,169	65,311	77,489	82,496	51,095
500	220,226	52,790	62,130	66,136	40,271
600	138,321	33,645	39,167	41,230	25,114
700	97,114	24,778	28,620	26,730	17,553
800	82,381	21,267	24,660	22,289	14,675
900	156,377	37,788	45,340	45,647	28,579
1000	131,164	31,797	37,877	38,584	23,715
1100	100,970	25,361	28,639	28,699	18,877
1200	72,905	18,514	20,481	20,433	13,477
1300	69,112	15,999	17,311	15,994	10,808
1400	51,621	14,177	14,531	13,443	9,470
1500	37,154	10,199	10,760	9,798	6,397
1750	15,805	5,503	4,082	3,384	2,836

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
2000	49,706	13,663	13,662	13,246	9,135
2500	26,595	7,664	7,371	6,874	4,686
3000	19,625	5,648	5,594	4,972	3,411
3500	14,808	4,183	4,309	3,752	2,564
4000	10,442	2,838	3,177	2,677	1,750
4500	6,164	1,556	2,019	1,545	1,044
5000	2,811	653	970	706	482
5500	811	164	280	225	142
Total profiles with at least one level	1,167,243	242,872	331,200	356,902	238,404

Table 7c. Number of Unflagged Standard Level Oxygen Values per Depth Level

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
0	324,627	78,542	86,976	93,306	66,322
10	327,216	79,255	88,003	94,453	66,176
20	316,521	77,175	85,387	91,173	63,560
30	307,381	75,263	82,745	88,343	61,787
50	287,205	70,859	77,764	81,708	57,642
75	249,157	61,987	67,747	70,830	49,344
100	217,485	54,798	59,432	61,645	42,356
125	186,477	48,708	49,134	53,096	36,356
150	178,725	46,279	48,213	50,932	34,051
200	140,672	36,988	37,974	39,699	26,687
250	163,407	43,087	43,428	46,469	31,235
300	146,525	38,818	38,917	41,679	27,928
400	126,102	33,875	33,201	35,923	23,856
500	109,682	29,099	29,196	31,517	20,592
600	67,493	18,402	17,901	19,003	12,639
700	45,747	13,195	12,685	11,513	8,712
800	38,936	11,336	11,167	9,525	7,189
900	92,497	25,034	24,820	25,997	17,356
1000	78,544	21,071	21,346	221,146	14,562
1100	64,094	17,757	17,121	17,418	12,251
1200	44,923	12,763	11,819	12,080	8,585
1300	38,772	11,143	10,341	10,210	7,359
1400	34,218	9,891	9,041	8,701	6,819
1500	24,017	7,048	6,548	6,021	4,524
1750	12,386	4,151	3,387	2,706	2,195

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
2000	40,735	11,681	10,985	10,370	7,945
2500	22,161	6,905	6,127	5,332	3,972
3000	16,407	5,014	4,637	3,993	2,917
3500	12,540	3,763	3,637	3,055	2,214
4000	9,008	2,550	2,725	2,235	1,575
4500	5,420	1,434	1,791	1,317	923
5000	2,546	616	883	619	451
5500	781	157	227	215	126
Total profiles with at least one level	354,627	85,416	95,340	102,520	72,224

Table 7d. Number of Unflagged Standard Level AOU Values per Depth Level

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
0	319,312	78,754	85,559	93,677	66,317
10	319,545	78,378	86,353	94,184	65,772
20	308,549	76,218	83,718	90,676	63,106
30	299,645	74,430	81,128	87,818	61,411
50	280,263	70,427	76,274	81,289	57,366
75	241,713	61,487	66,052	70,133	48,878
100	210,765	54,414	57,874	61,161	41,862
125	178,977	48,022	47,382	52,269	35,536
150	171,805	45,737	46,644	50,260	33,281
200	134,684	36,310	36,664	39,082	25,970
250	156,360	42,559	41,817	45,758	30,316
300	140,824	38,550	37,656	41,271	27,139
400	120,796	33,575	32,004	35,461	23,043
500	105,116	28,807	28,094	31,241	19,972
600	64,462	18,202	17,204	18,958	12,198
700	43,825	13,093	12,243	11,477	8,482
800	37,418	11,286	10,835	9,516	7,055
900	88,264	24,838	23,731	25,828	16,851
1000	75,003	20,943	20,480	22,138	14,061
1100	60,735	17,561	16,225	17,.288	11,825
1200	42,773	12,692	11,314	12,122	8,274
1300	36,891	11,052	9,895	10,147	7,129
1400	32,299	9,742	8,580	8,648	6,563
1500	22,915	6,980	6,321	6,033	4,449
1750	11,734	4,099	3,229	2,623	2,144

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
2000	39,234	11,719	10,664	10,551	7,864
2500	21,449	6,979	5,967	5,305	4,022
3000	15,928	5,048	4,552	3,998	2,967
3500	12,153	3,797	3,555	3,036	2,269
4000	8,714	2,580	2,663	2,242	1,591
4500	5,183	1,442	1,733	1,288	926
5000	2,441	617	855	609	449
5500	752	154	284	208	121
Total profiles with at least one level	351,835	86,362	94,663	103,546	72,686

Table 7e. Number of Unflagged Standard Level Percent Oxygen Saturation Values per Depth Level

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
0	320,299	77,482	85,791	92,364	65,563
10	320,688	77,088	86,541	92,845	64,994
20	309,660	74,919	83,898	89,341	62,321
30	300,735	73,124	81,309	86,494	60,626
50	281,300	69,129	76,446	79,950	56,593
75	242,667	60,251	66,214	68,881	48,140
100	211,598	53,229	58,028	59,969	41,172
125	179,705	46,910	47,497	51,150	34,88
150	172,541	44,638	46,792	49,164	32,673
200	135,277	35,410	36,798	38,194	25,492
250	156,990	41,476	41,944	44,669	29,705
300	141,348	37,558	37,754	40,255	26,577
400	121,221	32,703	32,108	34,566	22,554
500	105,537	28,022	28,192	30,441	19,542
600	64,765	17,645	17,268	18,404	11,892
700	44,030	12,677	12,285	11,125	8,271
800	37,611	10,901	10,871	9,234	6,881
900	88,657	24,023	23,824	25,065	16,396
1000	75,320	20,229	20,557	21,464	13,646
1100	61,002	16,946	16,302	16,747	11,461
1200	42,952	12,234	11,347	11,716	7,993
1300	37,015	10,641	9,910	9,812	6,934
1400	32,433	9,372	8,610	8,348	6,330
1500	23,003	6,721	6,326	5,801	4,316
1750	11,780	3,974	3,234	2,554	2,080

Depth Level (meters)	Annual	Winter	Spring	Summer	Fall
2000	39,412	11,259	10,693	10,176	7,567
2500	21,543	6,731	5,980	5,121	3,895
3000	15,992	4,862	4,564	3,848	2,879
3500	12,189	3,642	3,567	2,914	2,193
4000	8,739	2,471	2,668	2,147	1,532
4500	5,204	1,374	1,738	1,241	892
5000	2,452	597	860	583	433
5500	752	147	285	203	119
Total profiles with at least one level	352,884	84,986	94,844	102,120	71,857

APPENDIX A: Table 1. Ocean basins for which separate ranges were set

1. North Atlantic
2. Equatorial Atlantic
3. South Atlantic
4. North Pacific
5. Equatorial Pacific
6. South Pacific
7. North Indian
8. Equatorial Indian
9. South Indian
10. Mediterranean Sea*
11. Baltic Sea*
12. Black Sea*
13. Persian Gulf*
14. Red Sea*
15. Sulu Sea*
16. Arctic Area
17. Southern Ocean

* - no ranges for oxygen (ranges for closest basin used; i.e. North Indian ranges for Persian Gulf)

Table 2a. Temperature ranges for the Atlantic Ocean as a function of depth.

Depth	North Atlantic		Eq. Atlantic		South Atlantic	
	Low	High	Low	High	Low	High
0	-3.0	35.0	5.0	35.0	0.0	32.0
10	-3.0	35.0	5.0	35.0	0.0	32.0
20	-3.0	35.0	5.0	35.0	0.0	32.0
30	-3.0	32.0	5.0	35.0	0.0	32.0
50	-3.0	32.0	5.0	35.0	0.0	32.0
75	-2.0	32.0	5.0	35.0	0.0	32.0
100	-2.0	30.0	5.0	30.0	-1.5	32.0
125	-2.0	28.0	5.0	30.0	-1.5	30.0
150	-2.0	28.0	5.0	30.0	-1.5	30.0
200	-2.0	28.0	5.0	30.0	-1.5	30.0
250	-1.7	28.0	3.0	28.0	-1.5	28.0
300	-1.7	28.0	3.0	28.0	-1.5	28.0
400	-1.5	20.0	3.0	28.0	-1.5	28.0
500	-1.5	20.0	3.0	28.0	-1.5	28.0
600	-1.5	20.0	3.0	20.0	-1.5	20.0
700	-1.5	20.0	3.0	20.0	-1.5	20.0
800	-1.5	20.0	-0.5	20.0	-1.5	20.0
900	-1.5	20.0	-0.5	20.0	-1.5	20.0
1000	-1.5	18.0	-0.5	18.0	-1.5	18.0
1100	-1.5	18.0	-0.5	18.0	-1.5	18.0
1200	-1.5	18.0	-0.5	18.0	-1.5	18.0
1300	-1.5	18.0	-0.5	18.0	-1.5	18.0
1400	-1.5	18.0	-0.5	18.0	-1.5	18.0
1500	-1.5	18.0	-0.5	18.0	-1.5	18.0
1750	-1.5	13.0	-0.5	13.0	-1.5	13.0
2000	-1.5	13.0	-0.5	13.0	-1.5	13.0
2500	-1.5	13.0	-0.5	13.0	-1.5	13.0
3000	-1.5	7.0	-0.5	7.0	-1.5	7.0
3500	-1.5	7.0	-0.5	7.0	-1.5	7.0
4000	-1.5	7.0	-0.5	7.0	-1.5	7.0
4500	-1.5	7.0	-0.5	7.0	-1.5	7.0
5000	-1.5	7.0	-0.5	7.0	-1.5	7.0
5500	-1.5	5.0	-0.5	3.0	-1.5	3.0

Table 2b. Temperature ranges for the Pacific Ocean as a function of depth.

Depth	North Pacific		Eq. Pacific		South Pacific	
	Low	High	Low	High	Low	High
0	-3.0	35.0	5.0	35.0	-2.0	32.0
10	-3.0	35.0	5.0	35.0	-2.0	32.0
20	-3.0	35.0	5.0	35.0	-2.0	32.0
30	-3.0	35.0	5.0	35.0	-2.0	32.0
50	-3.0	35.0	5.0	35.0	-2.0	30.0
75	-3.0	35.0	5.0	35.0	-2.0	30.0
100	-3.0	30.0	5.0	30.0	-2.0	30.0
125	-3.0	30.0	3.0	30.0	-2.0	30.0
150	-3.0	30.0	3.0	30.0	-2.0	30.0
200	-3.0	30.0	3.0	30.0	-2.0	30.0
250	-3.0	30.0	3.0	28.0	-2.0	28.0
300	-3.0	28.0	3.0	28.0	-2.0	28.0
400	-3.0	28.0	3.0	28.0	-2.0	28.0
500	-3.0	28.0	0.0	28.0	-2.0	28.0
600	-3.0	20.0	0.0	20.0	-2.0	20.0
700	-3.0	20.0	0.0	20.0	-2.0	20.0
800	-3.0	20.0	0.0	20.0	-2.0	20.0
900	-3.0	20.0	0.0	20.0	-2.0	20.0
1000	-3.0	18.0	0.0	18.0	-2.0	18.0
1100	-3.0	18.0	0.0	18.0	-2.0	18.0
1200	-3.0	18.0	0.0	18.0	-2.0	18.0
1300	-3.0	18.0	0.0	18.0	-2.0	18.0
1400	-3.0	18.0	0.0	18.0	-2.0	18.0
1500	-3.0	18.0	0.0	18.0	-2.0	18.0
1750	-3.0	13.0	0.0	13.0	-2.0	13.0
2000	-3.0	13.0	0.0	13.0	-2.0	13.0
2500	-3.0	13.0	0.0	13.0	-2.0	13.0
3000	-3.0	7.0	0.0	7.0	-2.0	7.0
3500	-3.0	7.0	0.0	7.0	-2.0	7.0
4000	-1.5	7.0	-1.5	7.0	-1.5	7.0
4500	-1.5	7.0	-1.5	7.0	-1.5	7.0
5000	-1.5	7.0	-1.5	7.0	-1.5	7.0
5500	-1.5	3.0	-1.5	3.0	-1.5	3.0

Table 2c. Temperature ranges for the Indian Ocean as a function of depth.

Depth	North Indian		Eq. Indian		South Indian	
	Low	High	Low	High	Low	High
0	3.0	35.0	5.0	35.0	0.0	35.0
10	3.0	35.0	5.0	35.0	0.0	35.0
20	3.0	35.0	5.0	35.0	0.0	35.0
30	3.0	35.0	5.0	35.0	0.0	35.0
50	3.0	35.0	5.0	35.0	0.0	35.0
75	3.0	35.0	5.0	35.0	0.0	35.0
100	3.0	30.0	5.0	30.0	0.0	30.0
125	3.0	30.0	3.0	30.0	0.0	30.0
150	3.0	30.0	3.0	30.0	0.0	30.0
200	3.0	30.0	3.0	30.0	0.0	30.0
250	3.0	30.0	3.0	28.0	0.0	28.0
300	3.0	28.0	3.0	28.0	0.0	28.0
400	3.0	28.0	3.0	28.0	0.0	28.0
500	3.0	28.0	0.0	28.0	0.0	28.0
600	0.0	20.0	0.0	20.0	0.0	20.0
700	0.0	20.0	0.0	20.0	0.0	20.0
800	0.0	20.0	0.0	20.0	0.0	20.0
900	0.0	20.0	0.0	20.0	0.0	20.0
1000	0.0	18.0	0.0	18.0	0.0	18.0
1100	0.0	18.0	0.0	18.0	0.0	18.0
1200	0.0	18.0	0.0	18.0	0.0	18.0
1300	0.0	18.0	0.0	18.0	0.0	18.0
1400	0.0	18.0	0.0	18.0	0.0	18.0
1500	0.0	18.0	0.0	18.0	0.0	18.0
1750	0.0	13.0	0.0	13.0	0.0	13.0
2000	0.0	13.0	0.0	13.0	0.0	13.0
2500	0.0	13.0	0.0	13.0	0.0	13.0
3000	0.0	7.0	0.0	7.0	0.0	7.0
3500	0.0	7.0	0.0	7.0	0.0	7.0
4000	-1.5	7.0	-1.5	7.0	-1.5	7.0
4500	-1.5	7.0	-1.5	7.0	-1.5	7.0
5000	-1.5	7.0	-1.5	7.0	-1.5	7.0
5500	-1.5	3.0	-1.5	3.0	-1.5	3.0

Table 2d. Temperature ranges for the Mediterranean, Black and Baltic Seas as a function of depth.

Depth	Mediterranean		Black Sea		Baltic Sea	
	Low	High	Low	High	Low	High
0	0.0	34.0	0.0	27.0	-2.0	25.0
10	0.0	34.0	0.0	27.0	-2.0	25.0
20	0.0	34.0	0.0	27.0	-2.0	25.0
30	3.0	30.0	0.0	27.0	-2.0	25.0
50	3.0	30.0	3.0	30.0	-2.0	25.0
75	3.0	28.0	3.0	30.0	-2.0	25.0
100	3.0	26.0	3.0	30.0	-2.0	25.0
125	3.0	26.0	3.0	30.0	-2.0	25.0
150	3.0	26.0	5.0	30.0	-2.0	25.0
200	3.0	22.0	5.0	30.0	-2.0	16.0
250	3.0	22.0	5.0	25.0	-2.0	16.0
300	3.0	22.0	5.0	25.0	-2.0	16.0
400	3.0	20.0	5.0	20.0	-2.0	16.0
500	3.0	20.0	5.0	20.0	-2.0	16.0
600	3.0	20.0	5.0	20.0	-2.0	16.0
700	3.0	20.0	5.0	17.0	-2.0	16.0
800	3.0	20.0	5.0	17.0	-2.0	16.0
900	3.0	20.0	5.0	17.0	-2.0	16.0
1000	3.0	20.0	5.0	16.0	-2.0	16.0
1100	3.0	20.0	5.0	16.0	-2.0	16.0
1200	3.0	18.0	5.0	16.0	-2.0	16.0
1300	3.0	18.0	5.0	16.0	-2.0	16.0
1400	3.0	18.0	5.0	16.0	-2.0	16.0
1500	3.0	18.0	5.0	16.0	-2.0	16.0
1750	3.0	16.0	5.0	16.0	-2.0	16.0
2000	3.0	16.0	5.0	16.0	-2.0	16.0
2500	3.0	16.0	5.0	16.0	-2.0	16.0
3000	3.0	16.0	5.0	16.0	-2.0	16.0
3500	3.0	16.0	5.0	16.0	-2.0	16.0
4000	3.0	16.0	5.0	16.0	-2.0	16.0
4500	3.0	16.0	5.0	16.0	-2.0	16.0
5000	3.0	16.0	5.0	16.0	-2.0	16.0
5500	3.0	16.0	5.0	16.0	-2.0	16.0

Table 2e. Temperature ranges for the Persian Gulf, Red Sea and Sulu Seas as a function of depth.

Depth	Persian Gulf		Red Sea		Sulu Sea	
	Low	High	Low	High	Low	High
0	-3.0	35.0	14.0	35.0	0.0	35.0
10	-3.0	35.0	14.0	35.0	0.0	35.0
20	-3.0	35.0	14.0	34.0	0.0	35.0
30	-3.0	35.0	14.0	34.0	0.0	35.0
50	-3.0	35.0	13.0	32.0	0.0	35.0
75	-3.0	35.0	13.0	30.0	0.0	35.0
100	-3.0	32.0	13.0	30.0	0.0	30.0
125	-3.0	32.0	13.0	30.0	0.0	30.0
150	-3.0	32.0	13.0	30.0	0.0	30.0
200	-3.0	32.0	13.0	28.0	0.0	30.0
250	-3.0	32.0	13.0	28.0	0.0	28.0
300	-3.0	32.0	10.0	28.0	0.0	28.0
400	-3.0	32.0	10.0	28.0	0.0	28.0
500	-3.0	32.0	10.0	28.0	0.0	28.0
600	-3.0	32.0	10.0	26.0	0.0	20.0
700	-3.0	32.0	10.0	26.0	0.0	20.0
800	-3.0	32.0	10.0	26.0	0.0	20.0
900	-3.0	32.0	10.0	26.0	0.0	20.0
1000	-3.0	32.0	10.0	23.0	0.0	18.0
1100	-3.0	32.0	10.0	23.0	0.0	18.0
1200	-3.0	32.0	10.0	23.0	0.0	18.0
1300	-3.0	32.0	10.0	23.0	0.0	18.0
1400	-3.0	32.0	10.0	23.0	0.0	18.0
1500	-3.0	32.0	10.0	23.0	0.0	18.0
1750	-3.0	32.0	10.0	34.0	0.0	13.0
2000	-3.0	32.0	10.0	34.0	0.0	13.0
2500	-3.0	32.0	10.0	34.0	0.0	13.0
3000	-3.0	13.0	10.0	34.0	0.0	12.0
3500	-3.0	13.0	10.0	20.0	0.0	12.0
4000	-1.5	7.0	10.0	20.0	-1.5	12.0
4500	-1.5	7.0	10.0	20.0	-1.5	12.0
5000	-1.5	7.0	10.0	20.0	-1.5	12.0
5500	-1.5	7.0	10.0	20.0	-1.5	12.0

Table 2f. Temperature ranges for the Arctic Area and the Southern Ocean as a function of depth.

Depth	Arctic		Southern Ocean	
	Low	High	Low	High
0	-3.0	20.0	-3.0	15.0
10	-3.0	20.0	-3.0	15.0
20	-3.0	20.0	-3.0	15.0
30	-3.0	14.0	-3.0	15.0
50	-3.0	14.0	-3.0	15.0
75	-3.0	14.0	-3.0	15.0
100	-3.0	14.0	-3.0	15.0
125	-3.0	10.0	-3.0	15.0
150	-3.0	10.0	-3.0	15.0
200	-3.0	10.0	-3.0	15.0
250	-3.0	10.0	-3.0	15.0
300	-3.0	10.0	-3.0	15.0
400	-3.0	10.0	-3.0	15.0
500	-3.0	10.0	-3.0	15.0
600	-3.0	9.0	-3.0	10.0
700	-3.0	9.0	-3.0	10.0
800	-3.0	9.0	-3.0	10.0
900	-3.0	9.0	-3.0	10.0
1000	-3.0	8.0	-3.0	10.0
1100	-3.0	8.0	-3.0	10.0
1200	-3.0	8.0	-3.0	7.0
1300	-3.0	8.0	-3.0	7.0
1400	-3.0	8.0	-3.0	7.0
1500	-3.0	8.0	-3.0	7.0
1750	-3.0	8.0	-3.0	7.0
2000	-3.0	8.0	-3.0	7.0
2500	-3.0	8.0	-3.0	3.0
3000	-3.0	7.0	-3.0	3.0
3500	-3.0	7.0	-3.0	3.0
4000	-1.5	7.0	-1.5	3.0
4500	-1.5	7.0	-1.5	3.0
5000	-1.5	7.0	-1.5	3.0
5500	-1.5	3.0	-1.5	3.0

Table 3a. Salinity ranges for the Atlantic Ocean as a function of depth.

Depth	North Atlantic		Eq. Atlantic		South Atlantic	
	Low	High	Low	High	Low	High
0	0.0	40.0	0.0	40.0	0.0	40.0
10	27.0	38.2	20.0	37.6	28.0	38.5
20	28.3	38.2	28.0	37.4	28.0	38.0
30	28.5	38.2	31.0	37.4	30.6	38.0
50	28.9	38.0	31.4	37.4	31.0	38.0
75	28.9	38.0	31.8	37.4	31.2	38.0
100	29.4	38.0	31.8	37.4	31.4	38.0
125	29.4	38.0	31.8	37.4	31.4	37.8
150	29.6	37.2	31.8	37.2	31.4	37.4
200	29.9	37.4	31.8	37.0	31.4	36.6
250	30.3	37.1	32.0	37.0	31.4	36.2
300	30.8	36.8	32.2	36.8	31.6	36.0
400	30.8	36.6	32.4	36.6	32.0	35.8
500	31.2	36.6	33.7	36.5	34.0	35.5
600	32.2	36.6	33.7	36.0	34.1	35.1
700	33.0	36.6	33.6	35.8	34.1	35.1
800	33.0	36.6	33.6	35.6	34.1	35.0
900	33.0	36.6	33.6	35.6	34.1	34.9
1000	33.0	36.6	33.6	35.4	34.2	34.9
1100	33.0	36.6	33.6	35.4	34.2	34.9
1200	33.0	36.6	33.6	33.6	34.2	34.9
1300	33.0	36.6	33.6	33.6	34.3	34.9
1400	33.0	36.6	33.6	33.6	34.3	35.0
1500	33.0	36.6	33.6	33.8	34.4	35.0
1750	33.0	36.6	34.6	34.6	34.5	35.0
2000	33.0	36.0	34.7	34.7	34.6	35.0
2500	34.7	35.5	34.8	34.8	34.6	35.0
3000	34.8	35.4	34.8	34.8	34.66	35.0
3500	34.8	35.4	34.7	34.7	34.64	35.0
4000	34.8	35.4	34.5	34.5	34.62	35.0
4500	34.8	35.4	34.5	34.5	34.62	35.0
5000	34.8	35.4	34.5	34.5	34.62	35.0
5500	34.8	35.4	34.5	34.5	34.62	35.0

Table 3b. Salinity ranges for the Pacific Ocean as a function of depth.

Depth	North Pacific		Eq. Pacific		South Pacific	
	Low	High	Low	High	Low	High
0	0.0	40.0	0.0	40.0	0.0	40.0
10	25.0	37.0	28.6	37.0	28.0	37.0
20	30.0	36.5	29.0	37.0	28.0	37.0
30	30.0	36.5	29.6	37.0	29.0	37.0
50	31.0	36.0	30.2	37.0	30.0	36.7
75	31.0	36.0	31.0	37.0	31.0	36.7
100	31.5	36.0	31.5	37.0	31.0	36.7
125	31.5	36.0	31.5	36.8	31.0	36.7
150	32.0	35.8	31.5	36.8	31.0	36.7
200	32.0	35.8	31.5	36.7	31.2	36.0
250	32.0	35.8	31.8	36.3	31.5	36.0
300	32.0	35.8	31.8	36.3	32.0	36.0
400	32.0	35.5	31.8	36.2	34.2	36.0
500	32.4	35.25	32.75	36.1	34.2	35.5
600	32.6	35.25	33.0	36.0	34.2	35.25
700	32.6	35.25	33.0	35.9	34.2	35.0
800	33.2	35.25	33.75	35.8	34.2	35.0
900	33.6	35.25	33.8	35.5	34.2	35.0
1000	33.7	35.15	34.2	35.3	34.2	35.0
1100	33.7	35.15	34.2	35.3	34.3	35.0
1200	33.7	35.15	34.2	35.3	34.3	34.7
1300	33.7	35.15	34.2	35.3	34.3	34.7
1400	33.7	35.15	34.2	35.2	34.4	34.7
1500	33.8	35.0	34.4	35.2	34.4	34.8
1750	33.8	35.0	34.4	35.2	34.4	34.8
2000	34.0	35.0	34.4	35.2	34.4	34.8
2500	34.0	35.0	34.4	35.1	34.5	34.8
3000	34.0	35.0	34.2	35.1	34.5	34.8
3500	34.0	35.0	34.0	35.1	34.6	34.8
4000	34.0	35.0	34.0	35.4	34.6	34.8
4500	34.0	35.0	34.0	35.4	34.6	34.8
5000	34.0	35.0	34.0	35.4	34.6	34.8
5500	34.0	35.0	34.0	35.4	34.6	34.8

Table 3c. Salinity ranges for the Indian Ocean as a function of depth.

Depth	North Indian		Eq. Indian		South Indian	
	Low	High	Low	High	Low	High
0	0.0	40.0	0.0	40.0	0.0	40.0
10	28.0	38.0	26.0	38.0	30.0	36.4
20	29.8	38.0	31.0	37.4	31.4	36.4
30	30.2	38.0	31.2	37.0	31.6	36.4
50	31.2	38.0	31.6	36.8	31.9	36.3
75	32.2	38.0	31.6	36.8	32.0	36.3
100	32.4	37.0	31.6	36.6	32.0	36.2
125	32.4	37.0	31.8	36.5	32.0	36.2
150	32.6	37.0	31.8	36.4	32.0	36.1
200	33.4	37.0	31.8	36.4	32.0	36.0
250	33.6	37.0	32.0	36.3	32.2	36.0
300	33.7	37.0	32.0	36.2	32.2	35.8
400	34.0	36.5	32.4	36.2	32.4	35.6
500	34.6	36.5	34.3	36.0	34.1	35.4
600	34.85	36.3	34.4	36.0	34.15	35.3
700	34.85	36.3	34.4	35.75	34.2	35.2
800	34.85	36.2	34.45	35.75	34.2	35.0
900	34.85	36.0	34.45	35.75	34.2	34.9
1000	34.85	36.0	34.5	35.75	34.25	34.9
1100	34.8	35.9	34.5	35.75	34.25	34.9
1200	34.8	35.8	34.5	35.75	34.25	34.9
1300	34.8	35.6	34.55	35.6	34.3	34.9
1400	34.8	35.6	34.55	35.3	34.3	34.9
1500	34.75	35.6	34.55	35.2	34.35	34.9
1750	34.75	35.5	34.57	35.1	34.45	34.9
2000	34.7	35.4	34.6	35.0	34.55	34.9
2500	34.65	35.4	34.6	35.0	34.6	34.9
3000	34.65	35.4	34.6	35.0	34.6	34.9
3500	34.6	35.4	34.6	35.0	34.6	34.9
4000	34.6	35.4	34.6	35.0	34.6	34.9
4500	34.6	35.4	34.6	35.0	34.6	34.9
5000	34.6	35.4	34.6	35.0	34.6	34.9
5500	34.6	35.4	34.6	35.0	34.6	34.9

Table 3d. Salinity ranges for the Mediterranean Sea, Black Sea, and Baltic Sea as a function of depth.

Depth	Mediterranean		Black Sea		Baltic Sea	
	Low	High	Low	High	Low	High
0	0.0	40.0	0.0	25.0	0.0	35.0
10	0.0	40.0	0.0	25.0	0.0	35.0
20	0.0	40.0	0.0	25.0	0.0	35.0
30	0.0	40.0	0.0	25.0	0.0	35.0
50	12.0	40.0	10.0	40.0	0.0	35.0
75	12.0	40.0	10.0	40.0	0.0	35.0
100	31.0	40.0	12.0	40.0	0.0	35.0
125	31.0	40.0	12.0	40.0	1.0	35.0
150	31.0	40.0	12.0	40.0	1.0	35.0
200	31.0	40.0	12.0	40.0	1.0	25.0
250	31.0	40.0	12.0	40.0	1.0	25.0
300	31.0	40.0	12.0	35.0	1.0	25.0
400	31.0	40.0	12.0	33.0	1.0	25.0
500	31.0	40.0	12.0	30.0	1.0	25.0
600	33.0	40.0	12.0	30.0	1.0	25.0
700	33.0	40.0	15.0	30.0	1.0	25.0
800	33.0	40.0	15.0	28.0	1.0	25.0
900	33.0	40.0	15.0	28.0	1.0	25.0
1000	33.0	40.0	15.0	28.0	1.0	25.0
1100	33.0	40.0	18.0	25.0	1.0	25.0
1200	33.0	40.0	18.0	25.0	1.0	25.0
1300	33.0	40.0	18.0	25.0	1.0	25.0
1400	33.0	40.0	18.0	25.0	1.0	25.0
1500	33.0	40.0	18.0	25.0	1.0	25.0
1750	33.0	40.0	18.0	25.0	1.0	25.0
2000	33.0	40.0	18.0	25.0	1.0	25.0
2500	33.0	40.0	18.0	25.0	1.0	25.0
3000	33.0	40.0	18.0	25.0	1.0	25.0
3500	33.0	40.0	18.0	25.0	1.0	25.0
4000	33.0	40.0	18.0	25.0	1.0	25.0
4500	33.0	40.0	18.0	25.0	1.0	25.0
5000	33.0	40.0	18.0	25.0	1.0	25.0
5500	34.3	40.0	18.0	25.0	1.0	25.0

Table 3e. Salinity ranges for the Persian Gulf, Red Sea and Sulu Seas as a function of depth.

Depth	Persian Gulf		Red Sea		Sulu Sea	
	Low	High	Low	High	Low	High
0	0.0	42.0	0.0	44.0	0.0	40.0
10	0.0	42.0	0.0	44.0	0.0	40.0
20	0.0	42.0	0.0	44.0	0.0	40.0
30	0.0	42.0	0.0	44.0	0.0	40.0
50	20.0	42.0	20.0	43.0	20.0	40.0
75	20.0	42.0	20.0	43.0	20.0	40.0
100	30.0	42.0	30.0	43.0	30.0	40.0
125	30.0	42.0	30.0	43.0	30.0	40.0
150	30.0	42.0	30.0	43.0	30.0	40.0
200	30.0	42.0	30.0	43.0	30.0	40.0
250	30.0	42.0	30.0	43.0	30.0	40.0
300	30.0	42.0	30.0	43.0	30.0	40.0
400	33.0	42.0	33.0	43.0	33.0	40.0
500	33.0	42.0	33.0	43.0	33.0	40.0
600	33.0	42.0	33.0	43.0	33.0	40.0
700	33.0	42.0	33.0	43.0	33.0	40.0
800	33.0	42.0	33.0	43.0	33.0	40.0
900	33.0	42.0	33.0	43.0	33.0	40.0
1000	33.0	42.0	33.0	43.0	33.0	40.0
1100	33.0	42.0	33.0	43.0	33.0	38.0
1200	33.0	42.0	33.0	43.0	33.0	38.0
1300	33.0	42.0	33.0	43.0	33.0	38.0
1400	33.0	42.0	33.0	43.0	33.0	38.0
1500	33.0	42.0	33.0	43.0	33.0	38.0
1750	33.0	42.0	33.0	50.0	33.0	38.0
2000	33.0	42.0	33.0	50.0	33.0	38.0
2500	33.0	42.0	33.0	50.0	33.0	35.5
3000	33.0	35.5	33.0	50.0	33.0	35.5
3500	33.0	35.5	33.0	50.0	33.0	35.5
4000	33.0	35.5	33.0	50.0	33.0	35.5
4500	33.0	35.5	33.0	50.0	33.0	35.5
5000	33.0	35.5	33.0	50.0	33.0	35.5
5500	34.3	35.5	34.3	50.0	34.3	35.5

Table 3f. Salinity ranges for the Arctic Area and the Southern Ocean as a function of depth.

Depth	Arctic		Southern Ocean	
	Low	High	Low	High
0	0.0	40.0	0.0	40.0
10	0.0	40.0	26.0	36.75
20	0.0	40.0	28.0	36.75
30	0.0	40.0	29.0	36.5
50	0.0	40.0	30.0	36.5
75	26.0	38.0	30.5	36.5
100	26.0	38.0	30.5	36.5
125	26.0	38.0	30.5	36.5
150	26.0	38.0	31.0	36.5
200	26.0	38.0	31.0	36.25
250	26.0	38.0	31.0	36.0
300	30.0	38.0	31.0	36.0
400	33.0	37.0	31.5	35.75
500	33.0	37.0	32.0	35.5
600	33.0	37.0	33.0	35.5
700	33.0	37.0	33.8	35.35
800	33.0	37.0	33.8	35.0
900	33.0	37.0	34.0	35.0
1000	33.0	37.0	34.0	35.0
1100	33.0	36.0	34.0	35.0
1200	33.0	36.0	34.0	35.0
1300	33.0	36.0	34.0	34.9
1400	33.0	36.0	34.3	34.9
1500	33.0	36.0	34.3	34.9
1750	33.0	36.0	34.4	34.9
2000	33.0	36.0	34.4	34.9
2500	33.0	36.0	34.4	34.9
3000	33.0	36.0	34.4	34.9
3500	33.0	36.0	34.4	34.9
4000	33.0	36.0	34.4	34.9
4500	33.0	36.0	34.4	34.9
5000	33.0	36.0	34.4	34.9
5500	33.0	36.0	34.4	34.9

Table 4a. Oxygen ranges for the Atlantic Ocean as a function of depth.

Depth	North Atlantic		Eq. Atlantic		South Atlantic	
	Low	High	Low	High	Low	High
0	0.01	12.0	0.01	12.0	0.01	12.0
10	0.01	12.0	0.01	12.0	0.01	12.0
20	0.01	12.0	0.01	12.0	0.01	12.0
30	0.01	12.0	0.01	12.0	0.01	12.0
50	0.01	12.0	0.01	12.0	0.01	12.0
75	0.01	9.5	0.01	9.5	0.01	9.5
100	0.01	9.5	0.01	9.5	0.01	9.5
125	0.01	9.5	0.01	9.5	0.01	9.5
150	0.01	9.5	0.01	9.5	0.01	9.5
200	0.01	9.0	0.01	9.0	0.01	9.0
250	0.01	9.0	0.01	9.0	0.01	9.0
300	0.01	8.5	0.01	8.0	0.01	8.0
400	0.01	8.5	0.01	8.0	0.01	8.0
500	0.01	8.5	0.01	8.0	0.01	8.0
600	0.01	8.5	0.01	7.1	0.01	7.1
700	0.01	8.5	0.01	7.1	0.01	7.1
800	0.01	8.5	0.01	7.1	0.01	7.1
900	0.01	8.5	0.01	7.1	0.01	7.1
1000	0.01	8.5	0.01	7.1	0.01	7.1
1100	0.01	8.5	0.01	7.1	0.01	7.1
1200	0.01	8.5	0.01	7.1	0.01	7.1
1300	0.01	8.5	0.01	7.1	0.01	7.1
1400	0.01	7.1	0.01	7.1	0.01	7.1
1500	0.01	7.1	0.01	7.1	0.01	7.1
1750	0.01	7.1	0.01	7.1	0.01	7.1
2000	0.01	7.1	0.01	7.1	0.01	7.1
2500	0.01	7.1	0.01	7.1	0.01	7.1
3000	0.01	7.1	0.01	7.1	0.01	7.1
3500	0.01	7.1	0.01	7.1	0.01	7.1
4000	0.01	7.1	0.01	7.1	0.01	7.1
4500	0.01	6.9	0.01	6.0	0.01	6.0
5000	0.01	6.9	0.01	6.0	0.01	6.0
5500	0.01	6.9	0.01	6.0	0.01	6.0

Table 4b. Oxygen ranges for the Pacific Ocean as a function of depth.

Depth	North Pacific		Eq. Pacific		South Pacific	
	Low	High	Low	High	Low	High
0	0.01	12.0	0.01	12.0	0.01	12.0
10	0.01	12.0	0.01	12.0	0.01	12.0
20	0.01	12.0	0.01	12.0	0.01	12.0
30	0.01	12.0	0.01	12.0	0.01	12.0
50	0.01	12.0	0.01	12.0	0.01	12.0
75	0.01	9.5	0.01	9.5	0.01	9.5
100	0.01	9.5	0.01	9.5	0.01	9.5
125	0.01	9.5	0.01	9.5	0.01	9.5
150	0.01	9.5	0.01	9.5	0.01	9.5
200	0.01	9.0	0.01	9.0	0.01	9.0
250	0.01	9.0	0.01	9.0	0.01	9.0
300	0.01	7.5	0.01	6.4	0.01	6.4
400	0.01	7.5	0.01	6.4	0.01	6.4
500	0.01	6.4	0.01	6.4	0.01	6.4
600	0.01	6.4	0.01	6.4	0.01	6.4
700	0.01	6.4	0.01	6.4	0.01	6.4
800	0.01	6.4	0.01	6.4	0.01	6.4
900	0.01	6.4	0.01	6.4	0.01	6.4
1000	0.01	6.4	0.01	6.4	0.01	6.4
1100	0.01	6.4	0.01	6.4	0.01	6.4
1200	0.01	6.3	0.01	6.3	0.01	6.3
1300	0.01	6.3	0.01	6.3	0.01	6.3
1400	0.01	6.3	0.01	6.3	0.01	6.3
1500	0.01	6.3	0.01	6.3	0.01	6.3
1750	0.01	6.3	0.01	6.3	0.01	6.3
2000	0.01	6.3	0.01	6.3	0.01	6.3
2500	0.01	6.3	0.01	6.3	0.01	6.3
3000	0.01	6.3	0.01	6.3	0.01	6.3
3500	0.01	6.3	0.01	6.3	0.01	6.3
4000	0.01	6.3	0.01	6.3	0.01	6.3
4500	0.01	6.3	0.01	6.3	0.01	6.3
5000	0.01	6.3	0.01	6.3	0.01	6.3
5500	0.01	6.3	0.01	6.3	0.01	6.3

Table 4c. Oxygen ranges for the Indian Ocean as a function of depth.

Depth	North Indian		Eq. Indian		South Indian	
	Low	High	Low	High	Low	High
0	0.01	12.0	0.01	12.0	0.01	12.0
10	0.01	12.0	0.01	12.0	0.01	12.0
20	0.01	12.0	0.01	12.0	0.01	12.0
30	0.01	12.0	0.01	12.0	0.01	12.0
50	0.01	12.0	0.01	12.0	0.01	12.0
75	0.01	9.5	0.01	9.5	0.01	9.5
100	0.01	9.5	0.01	9.5	0.01	9.5
125	0.01	9.5	0.01	9.5	0.01	9.5
150	0.01	9.5	0.01	9.5	0.01	9.5
200	0.01	9.0	0.01	9.0	0.01	9.0
250	0.01	9.0	0.01	9.0	0.01	9.0
300	0.01	8.0	0.01	8.0	0.01	8.0
400	0.01	8.0	0.01	8.0	0.01	8.0
500	0.01	8.0	0.01	8.0	0.01	8.0
600	0.01	7.1	0.01	7.1	0.01	7.1
700	0.01	7.1	0.01	7.1	0.01	7.1
800	0.01	7.1	0.01	7.1	0.01	7.1
900	0.01	7.1	0.01	7.1	0.01	7.1
1000	0.01	7.1	0.01	7.1	0.01	7.1
1100	0.01	7.1	0.01	7.1	0.01	7.1
1200	0.01	7.1	0.01	7.1	0.01	7.1
1300	0.01	7.1	0.01	7.1	0.01	7.1
1400	0.01	7.1	0.01	7.1	0.01	7.1
1500	0.01	7.1	0.01	7.1	0.01	7.1
1750	0.01	7.1	0.01	7.1	0.01	7.1
2000	0.01	7.1	0.01	7.1	0.01	7.1
2500	0.01	7.1	0.01	7.1	0.01	7.1
3000	0.01	7.1	0.01	7.1	0.01	7.1
3500	0.01	7.1	0.01	7.1	0.01	7.1
4000	0.01	7.1	0.01	7.1	0.01	7.1
4500	0.01	6.0	0.01	6.0	0.01	6.0
5000	0.01	6.0	0.01	6.0	0.01	6.0
5500	0.01	6.0	0.01	6.0	0.01	6.0

Table 4d. Oxygen ranges for the Arctic Area and the Southern Ocean as a function of depth.

Depth	Arctic		Southern Ocean	
	Low	High	Low	High
0	0.01	12.0	0.01	12.0
10	0.01	12.0	0.01	12.0
20	0.01	12.0	0.01	12.0
30	0.01	12.0	0.01	12.0
50	0.01	12.0	0.01	12.0
75	0.01	9.0	0.01	9.0
100	0.01	9.0	0.01	9.0
125	0.01	9.0	0.01	9.0
150	0.01	9.0	0.01	9.0
200	0.01	9.0	0.01	9.0
250	0.01	9.0	0.01	9.0
300	0.01	9.0	0.01	9.0
400	0.01	9.0	0.01	9.0
500	0.01	9.0	0.01	9.0
600	0.01	8.0	0.01	8.0
700	0.01	8.0	0.01	8.0
800	0.01	8.0	0.01	8.0
900	0.01	8.0	0.01	8.0
1000	0.01	8.0	0.01	8.0
1100	0.01	8.0	0.01	8.0
1200	0.01	8.0	0.01	8.0
1300	0.01	8.0	0.01	8.0
1400	0.01	8.0	0.01	8.0
1500	0.01	8.0	0.01	8.0
1750	0.01	7.5	0.01	7.0
2000	0.01	7.5	0.01	7.0
2500	0.01	7.5	0.01	7.0
3000	0.01	7.5	0.01	7.0
3500	0.01	7.5	0.01	7.0
4000	0.01	7.5	0.01	7.0
4500	0.01	7.0	0.01	7.0
5000	0.01	7.0	0.01	7.0
5500	0.01	7.0	0.01	7.0

APPENDIX B. DATA FLAGS AND DATA AVAILABILITY

The flagged observed and standard level nutrient profiles are available from the National Oceanographic Data Center on CD-ROM, exabyte tape and other media. Data were flagged at each quality control step and the flagged data excluded from further checks. The flags were added to the header data (0 for a good profile and 1 if the entire profile was excluded from further quality control) and for each parameter at every depth in the profile. The following is a description of the flags which are used to identify errors in the nutrient data.

A. Depth error flags

If the second of two successive depths is shallower than the first (a depth inversion), the second depth is marked with a flag value = 1. Each depth following the second depth, which is also shallower than the first depth, is flagged with a value = 1. If three successive depths are shallower than the first depth, every depth reading following the first will be marked with a value = 1. Likewise, if two successive depth readings are equal, the second reading will be marked with a value = 1. All useable depths are marked with a value = 0.

B. Profile error flags

Flags on all values of an individual parameter in a profile, as well as flags applied to individual observations of a parameter, pertain to the quality control done to create the analyzed fields (climatologies). Standard deviation checks are done only on standard level data. This check calculates the mean and standard deviation of each parameter for 5 degree square latitude longitude boxes and flags values which are more than 3-5 standard deviations from the mean. (3 for open ocean, 5 for coastal, 4 for near coastal.) If a profile contains two or more standard deviation failures, the whole profile is flagged. This is done for annual (all parameters), seasonal (temperature, salinity, oxygen) and monthly (temperature, salinity) periods. Density stability checks are only for temperature and salinity profiles. The criteria for an instability is described by Levitus (1982). Two or more instabilities cause a profile to be flagged. Although stability checks are performed on standard level data, the observed profile is flagged as follows. While observed level density inversions are flagged at individual depths, no observed level profiles were flagged for having two or more inversions, this flag although included in observed level whole profile flag, pertains to the standard level profile. Flags such as density and temperature inversions are placed at both observed and standard levels. The cruise flag denotes a cruise with consistently anomalous data. Bullseye flags apply to depths with anomalous data which cause ripple effects, or bullseyes in analyzed data.

C. Definition of Flags

(1) FLAGS FOR ENTIRE PROFILE (AS A FUNCTION OF PARAMETER)

0 - accepted profile
1 - failed annual standard deviation check
2 - two or more density inversions (Levitus, 1982 criteria)
3 - flagged cruise
4 - failed seasonal standard deviation check
5 - failed monthly standard deviation check
6 - flag 1 and flag 4
7 - flag 1 and flag 5
8 - flag 4 and flag 5
9 - flag 1 and flag 4 and flag 5

(2) FLAGS ON INDIVIDUAL OBSERVATIONS

(a) Depth Flags

0 - accepted value
1 - error in recorded depth (same or less than previous depth)
2 - temperature inversion of magnitude > 0.3 /meter
3 - temperature gradient of magnitude > 0.7 /meter
4 - temperature gradient and inversion

(b) Observed Level Flags

0 - accepted value
1 - range outlier (outside of broad range check)
2 - density inversion
3 - failed range check and density inversion check

(3) Standard Level Flags

0 - accepted value
1 - bullseye marker
2 - density inversion
3 - failed annual standard deviation check
4 - failed seasonal standard deviation check
5 - failed monthly standard deviation check
6 - failed annual and seasonal standard deviation check
7 - failed annual and monthly standard deviation check
8 - failed seasonal and monthly standard deviation check
9 - failed annual, seasonal and monthly standard deviation check

APPENDIX C. FORTRAN PROGRAM TO READ AND WRITE OBSERVED LEVEL AND STANDARD LEVEL VERTICAL PROFILE DATA

```
      program OCLdemo
c
c program to print out 20 profiles for all parameters in one record
c from NODC's Ocean Climate Laboratory quality controlled ASCII observed level
c or standard level data
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c
c    HEADER INFORMATION:
c
c        cc - NODC country code, see country code list
c        icruise - NODC cruise code (NODC files only)
c        rlat - latitude in degrees down to thousandths
c        rlon - longitude in degrees down to thousandths
c        NOTE: negative latitudes are south, negative longitudes are west
c        iyear - year of profile
c        month - month of profile
c        iday - day of profile
c        chime - 6 characters representing GM time
c                in hours, down to thousandths
c                blanks mean time not recorded
c        nprofile - OCL profile number
c        numlevels - number of recorded levels
c        isoor - 1 for standard levels 0 for observed levels
c        nparm - number of parameters recorded in this entry
c
c    PARAMETER FILE INFORMATION
c
c         newfile - FORTRAN file number
c         data - data array
c         depth - observed depths
c         maxlevel - maximum number of levels (6000)
c         maxparm - maximum number of parameters (15)
c         ierror - flag for all parameter values in a profile
c         iderror - individual depth parameter flags
c         ip2 - parameter codes
c
c         These are the codes presently used
c         PARAMETER   # CODE
c         Temperature    1
c         Salinity       2
c         Oxygen         3
```

```
c       Phosphate       4
c       TotalPhos       5
c       Silicate 6
c       Nitrite   7
c       Nitrate  8
c       pH              9
c
c       bmiss - missing value indicator
c       amiss - ASCII missing value indicator
c       ieof - end of file marker (1 if end of file reached, otherwise 0)
c       nfile, ifile - input and output files
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c
      parameter maxlevel=6000, maxparm=15, kdim=33
      parameter bmiss=-1.E10, amiss=-99.99
c
      character*2 cc
      character*6 chime
      character*80 nfile, ifile
      character*4 param(9)
c
      dimension data(maxlevel,maxparm), depth(maxlevel),dz(kdim)
      dimension ierror(maxparm),iderror(maxlevel,0:maxparm)
      dimension ip3(0:maxparm)
c
      data dz/ 0., 10., 20., 30., 50., 75., 100., 125., 150.,
     * 200., 250., 300., 400., 500., 600., 700., 800., 900.,
     * 1000., 1100., 1200., 1300., 1400., 1500., 1750., 2000.,
     * 2500., 3000., 3500., 4000., 4500., 5000., 5500./
c
      data param/'Temp','Sal','O2','PO4','tP','Si','NO2','NO3','ph'/
c
c Read and open input data file name
c
      write(6,*) 'Input File Name'
      read(5,'(a80)') nfile
      newfile=11
      open(newfile,file=nfile,status='old')
c
c Read and open output file name
c
      write(6,*) 'Input Output File Name'
      read(5,'(a80)') ifile
      open(12,file=ifile,status='unknown')
```

```
c
c Begin loop to read and write 20 profiles
      do 50 ij=1,20
c
c Call subroutine to read data
c
       call OCLread(cc,icruise,rlat,rlon,iyear,month,
     * iday,chime,jjx,numlevels,isoor,nparm,newfile,data,
     * depth,maxlevel,maxparm,ierror,iderror,ip3,bmiss,ieof)
c
c end of file statement
       if ( ieof.gt.0 ) goto 4
c
c Read in depths if standard level data (isoor .eq. 1)
c
       if ( isoor.eq.1.and.ij.eq.1) then
        do 60 i=1,kdim
60         depth(i)=dz(i)
       endif
c
c Write out header information to file
c
       write(12,799)
       write(12,800) cc,icruise,rlat,rlon,iyear,month,iday,
     * chime,jjx,numlevels,(ierror(np),np=1,nparm)
799   format('cc',3x,'cruise',4x,'lat',5x,'lon',3x,'year',1x,'mm',1x,
     *       'dd',2x,' GMT',3x,'profile',1x,'depths',2x,'flag')
800   format(a2,1x,i8,1x,f7.2,1x,f8.2,2x,i4,1x,i2,1x,i2,
     * 1x,a5,1x,i8,1x,i4,4x,i1)
c
c Write subtitle (depth, parameter, flag) to file
c
      write(12,801)(param(ip3(mm)), mm=1,nparm)
801   format(2x,'Depth',1x,'F',10(4x,a4,1x,'F'))
c
c Write data to file
      do 80 n=1,numlevels
       write(12,802) depth(n),iderror(n,0),
     *              (data(n,ip3(j)),iderror(n,ip3(j)),j=1,nparm)
80    continue
802   format(1x,f6.0,1x,i1,2x,10(f6.2,1x,i1,2x))
c
      write(12,'(/)')
c
50    continue
```

```
 4    continue
c
      stop
      end
c
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      subroutine OCLread(cc,icruise,rlat,rlon,iyear,month,
     * iday,chime,nprofile,numlevels,isoor,nparm,newfile,data,
     * depth,maxlevels,maxparm,ierror,iderror,ip2,bmiss,ieof)
c
c     subroutine to read OCL ascii format
c

      parameter amiss=-99.99
      character cc*2, cholder*80, chime*6
c
      dimension data(maxlevels,maxparm),iderror(maxlevels,0:maxparm)
      dimension depth(maxlevels),ierror(maxparm),ip2(0:maxparm)
c
c read in header
c
      if ( ieof .lt. 1 ) then
c
       read(newfile,800,end=4) cc,icruise,rlat,rlon,iyear,month,iday,
     * chime,nprofile,numlevels,isoor,nparm,(ip2(i),ierror(ip2(i)),
     * i=1,nparm)
c
800    format(a2,i5,f7.3,f8.3,i4,i2,i2,a6,i8,i4,i1,i2,10(i2,i1))
c
c calculate how many lines this profile occupies
c
       isoor2=0
       iaddline=0
       if ( isoor.eq.0 ) isoor2=1
       nlines= ((nparm+isoor2)*numlevels)
       if ( mod(nlines,10) .gt. 0 ) iaddline=1
       nlines=(nlines/10)+iaddline
c
c read in data
c
       levels=0
       mread=nparm
       iend=0
c
```

```
       do 40 l=1,nlines
        read(newfile,'(a80)') cholder
c

        do 45 n=1,10
         m2=(n-1)*8+1
         if ( mread .eq. nparm ) then
c
          if ( levels .eq. numlevels ) then
           iend=1
          else
           levels=levels+1
           mread=0
           idp=1
          endif
         endif
c
         if ( iend .lt. 1 ) then
c
         if ( idp .eq. 1 .and. isoor .eq. 0 ) then
          read(cholder(m2:m2+7),'(f7.1,i1)')
     *     depth(levels),iderror(levels,0)
          idp=0
         else
          mread = mread + 1
          read(cholder(m2:m2+7),'(f7.3,i1)')
     *     data(levels,ip2(mread)),iderror(levels,ip2(mread))
c
          if ( data(levels,ip2(mread)).lt.amiss+1. )
     *      data(levels,ip2(mread)) = amiss
          if ( data(levels,ip2(mread)).eq.bmiss)
     *      data(levels,ip2(mread)) = amiss
         endif
        endif
c
45      continue
40      continue
c
      endif
      return
c
4      ieof = 1
      return
c
      end
```

Appendix D. One-degree horizontal co-ordinate system of the analyzed fields

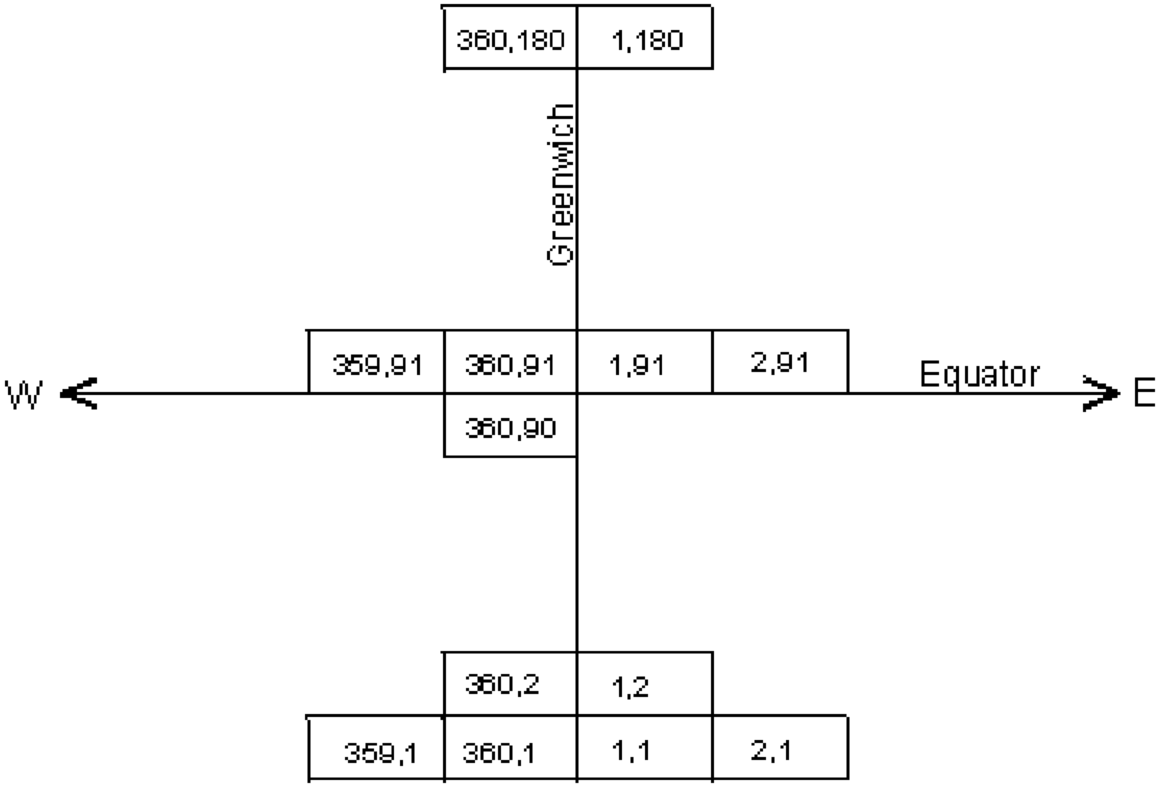
Each element (i,j) of an analyzed field dimensioned (360,180), is considered to represent the value at the center of a one degree latitude - longitude square.

Longitude denoted by the variable "i", varies from 1 at 0.5 E to 360 at 0.5 W

Latitude denoted by the variable "j", varies from 1 at 89.5 S to 180 at 89.5 N

The point (1,1) is the value at 0.5 E, 89.5 S
The point (218,20) is the value at 142.5 W, 70.5 S

The point (360,91) is the value at 0.5 W, 0.5 N

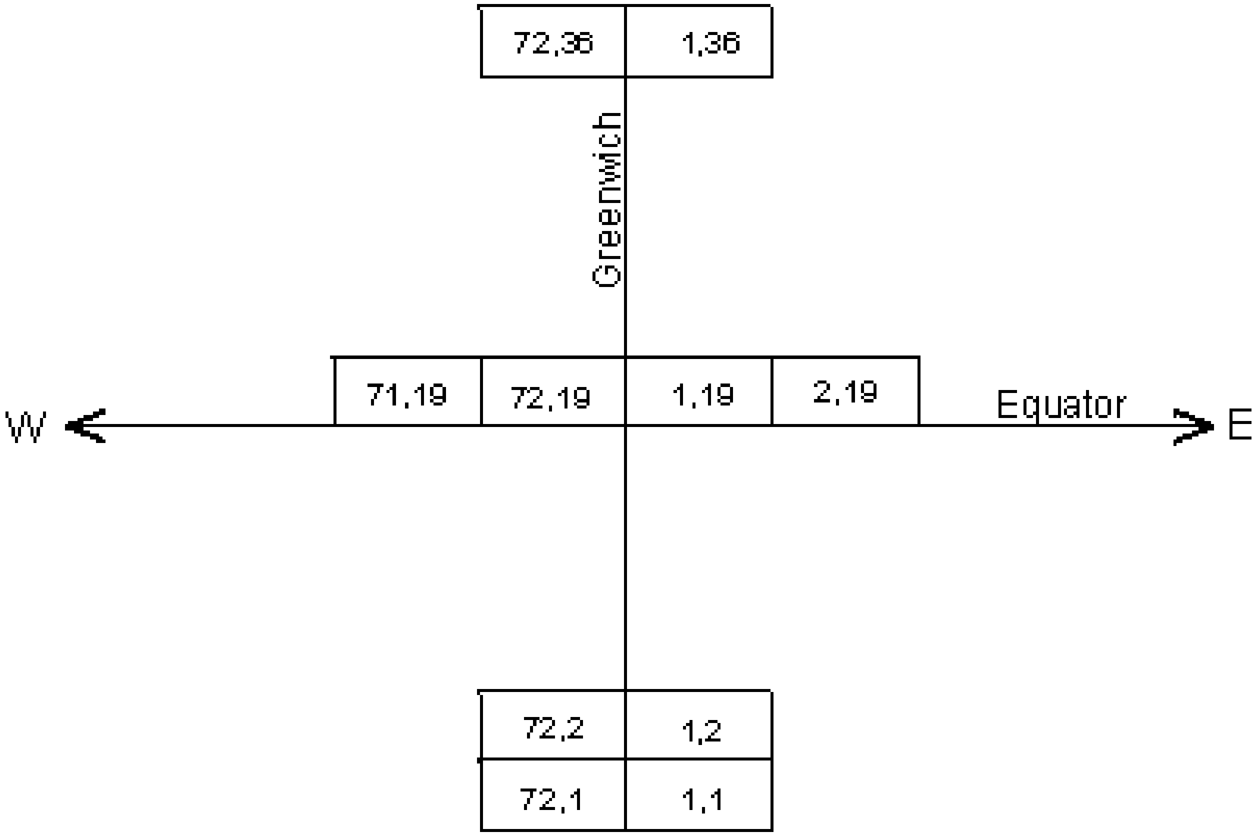


Appendix E. Five-degree horizontal co-ordinate system of the analyzed fields

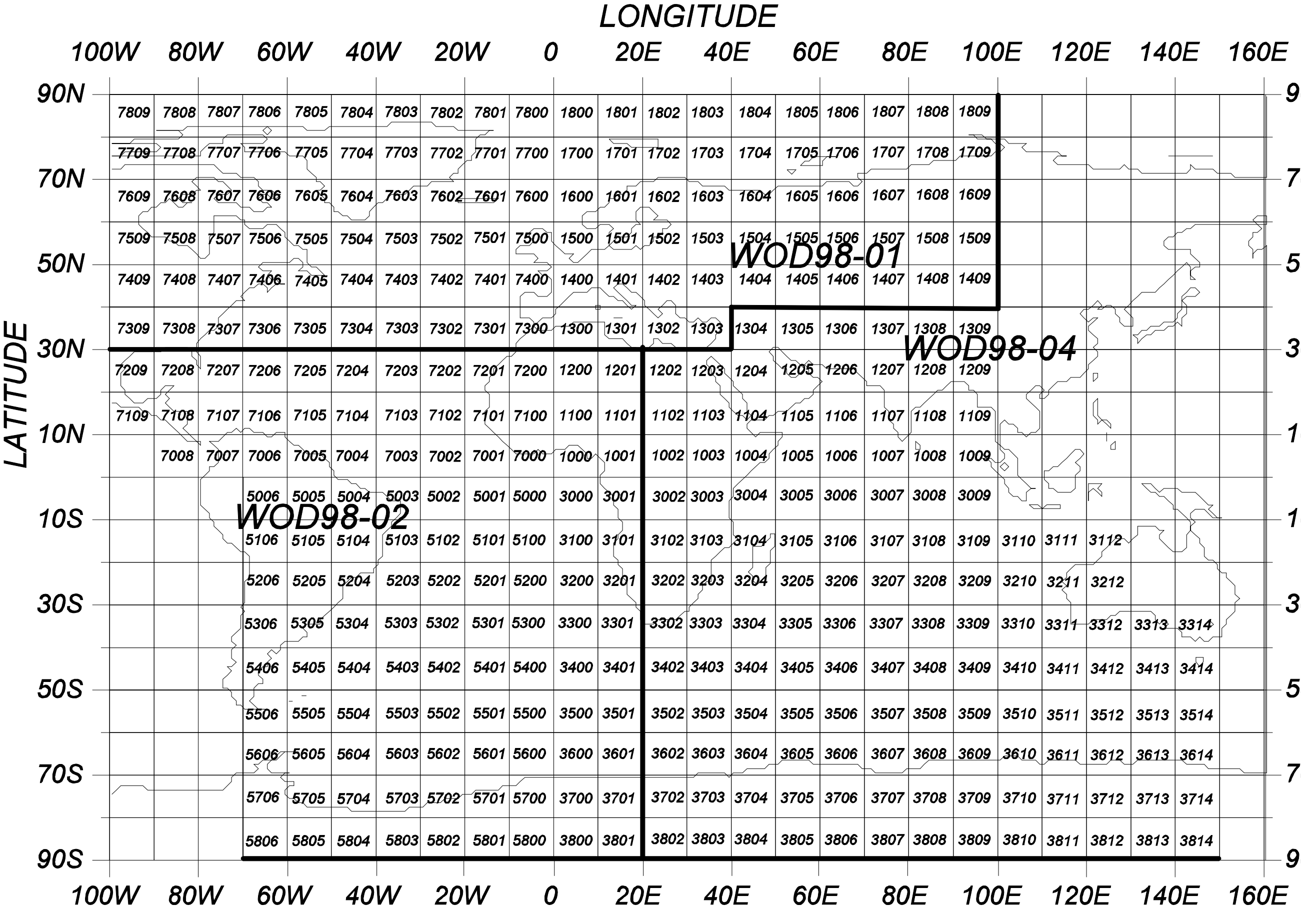
Each element F (i,j) of an analyzed field F, where F is dimensioned F(72,36), is considered to represent the value at the center of a five-degree latitude longitude square.

Longitude denoted by the variable "i", varies from 1 at 2.5' E to 72 at 2.5' W

Latitude denoted by the variable "j", varies from 1 at 87.5' S to 36 at 87.5' N



Appendix F: WMO square chart for the Atlantic and Indian Oceans



Appendix F: WMO square chart for the Atlantic and Indian Oceans