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QUALITY CONTROL AND PROCESSING OF HISTORICAL OCEANOGRAPHIC NUTRIENT DATA

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The data used are the master oceanographic data archives maintained by NODC/WDC-A as well as data acquired as a result of the NODC Data Archaeology and Rescue (NODAR) project and the IODE/IOC Global Oceanographic Data Archaeology and Rescue (GODAR) project. We would like to acknowledge the scientists who have submitted their data to national and regional data centers and the data managers at the various data centers.

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ABSTRACT

This paper is a description of the procedures used by the Ocean Climate Laboratory (OCL) in the quality control of the historical oceanographic nutrient data archived at the National Oceanographic Data Center (NODC). These procedures involve: (1) range checks of the observed level data for each major ocean basin as a function of depth; (2) statistical check of the interpolated standard level data; and (3) a check for unrealistic features after an initial computation of the objective analysis. Data were flagged along each step of the quality control and the flagged data excluded from further checks. The flagged observed and standard level data are available on CD-ROM.

INTRODUCTION

Oceanographers need quality data in order to understand the temporal and spatial variability of physical, chemical and biological parameters in the oceans. A high quality database requires development of procedures which insure the integrity of the data. 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. This paper describes the quality control procedures used to identify erroneous or non-representative measurements of phosphate, nitrate and silicate contained in the NODC Oceanographic Station Data archives (SD file) plus additional data not yet archived (SD2 file).

Analysis of historical nutrient data involves combining data collected and processed using different methodologies and precisions. Reliable methods for the measurement of low concentrations of nutrients in seawater were not used until the 1920's (Riley and Chester, 1971; Raymont, 1980). Historically, nutrients have been measured manually using spectrophotometric methods such as those described by Stricklan6 and Parsons (1972). These methods have generally been replaced by automated methods such as the Technicon Autoanalyzer (Technicon Industrial Methods, 1969) and the chemiluminescence analyzer for measuring nanomolar concentrations of nitrate (Garside, 1982). Further descriptions of methods can be found in Wood *et al.* (1967), Technicon Industrial Methods (1969, 1972), Coote *et al.* (1970, 1973), Stephens (1970), Atlas *et al.* (1971), Strickland and Parsons (1972), Pilson *et al.* (1973) and Parsons *et al.* (1984). Sapozhnikov *et al.* (1988) describe the methods used in the Former Soviet Union for the analysis of micronutrients as well as other seawater components.

A major concern is whether data collected using manual vs. automated methods can be combined into one coherent dataset as is the case in the NODC SD file. A comparison study between automated and manual methods based on the CSIRO Marine Laboratory data bank concluded there was good agreement between the two methods for phosphate but not silicate or nitrate (Airey, 1987; Airey and Sandars, 1987). Further investigation showed higher values in the manual measurement of nitrate between 1975-1984 were due to incorrect use of the standard curve; the discrepancy in silicate results was due to the use of silicate-containing artificial water in the preparation of the reagent blanks. Intercalibration experiments by the International Council for the Exploration of the Seas (ICES) in the late 1960's found the differences in results between laboratories due to problems in the standardization procedures (Koroleff *et al.*,1977).

In general, comparison between methods for all three nutrients show that results from both methods are within the experimental deviations (Berberian and Barcelona, 1979; Airey and Sandars, 1987) except at low concentrations where there is a loss of sensitivity in the automated methods. Berberian and Barcelona (1979) conclude the advantage of the AutoAnalyzer methods (economy and speed of sample) make up for the loss of sensitivity in low concentration areas.

The quality control of historical nutrient data was undertaken to prepare objective analysis maps of the annual mean distribution of nutrients in the world oceans (Conkright *et al.,* 1994).

DATA SOURCES AND DISTRIBUTIONS

The data used in this project are all the data found in the National Oceanographic Data Center's archived Oceanographic Station Data (SD file) as of the first quarter of 1993. Levitus and Gelfeld (1992) show global distribution maps of the data held in this file for all years (1900-1992). In addition, 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 study. A description of the NODAR and GODAR projects can be found in Levitus *et al* (1994). The NODAR and GODAR data sets are in a separate file named SD2 (since they have not yet been archived) and will be referred to as such throughout the text. Data in the SD2 file includes the following:
1. Australian Station Data
2. German Station Data
3. Icelandic Station Data
4. ICES (International Center for the Exploration of the Sea) Station Data
5. Japanese NODC Station Data
6. Korean NODC Station Data
7. Combined Mediterranean Station Data
8. Miscellaneous ship of opportunity Station Data
9. Pacific Institute of Oceanology (Russia) South China Sea Station Data
10. SIO (Scripps Institute of Oceanography) Southtow cruise Station Data.

The unit used for nutrients is micromolar (μM).

Table 1 lists the number of phosphate, nitrate and silicate observations as a function of observed depth levels for the combined SD and SD2 files. Shown in this table is the number of observed data points that occur in the depth range centered around each standard level. The depth range for the sea surface is 0-5 m. At all other standard levels, the depth range is defined as the region between the midpoints of the standard level being considered and the adjacent standard levels above and below. The standard levels used in this study are listed in Table 1.

The terms "standard level data" and "observed level data" are required to understand the data distribution and tables we present in this paper. We refer to the actual measured value of an *in* *situ* oceanographic parameter as an "observation", and to the depth at which such a measurement was made as "observed level depth". We may refer to such data as "observed level data". Before the advent of oceanographic instrumentation that measure at high frequencies in the vertical, oceanographers often attempted to make measurements at selected "standard levels" in the water column. For many analysis purposes observed level data are interpolated to standard observation levels, if they do not occur exactly at a standard observation level. The standard depths selected for this sturdy are listed in Table 1 and include the 30 NODC standard depths and three additional levels at 3500, 4500 and 5500 meters depth.

Table 2 shows there are a total of 184,153 phosphate profiles, 75,403 nitrate profiles, and 110,413 silicate profiles. The greater number of samples for phosphate results from the fact that rapid and accurate measurements of low nutrient concentrations phosphate were possible earlier for phosphate than for nitrate and silicate (1920's to early 1960's). Rapid and convenient shipboard techniques for nitrate measurements were not developed until 1963 (Morris and Riley, 1963). Global distribution maps of these data are shown in Conkright *et al.* (1994). These maps are useful for identifying possible bias in the data analysis due to missing data or few values.

The seasonal distribution of phosphate, nitrate and silicate profiles as a function of year is shown in Figs. la, 1b and 1c respectively. These figures show possible bias in using an all-season database to examine properties which have strong seasonal signals. For example, most expeditions to high latitudes are in the summer season, so a bias towards low nutrient values (due to uptake by phytoplankton) is expected when compositing these data. Nutrient measurements peaked during the mid-1960's and early 1970's, particularly in the spring and summer months. Table 2 summarizes the number of profiles for each season in the SD and SD2 files.

Because of differences in the horizontal and vertical distribution of nutrients in different ocean basins (Levitus *et al.*, 1993; Conkright *et al.*, 1994), the oceans were divided into eleven separate basins as shown in Fig. 2. Fig. 3 shows the total number of phosphate, nitrate and silicate observations in each of these basins.

QUALITY CONTROL

The quality control procedures used by the NODC on the SD file parameters are described in the NODC User's Guide (1993). These procedures focus on problems such as valid ship speeds and correct latitudes and longitudes. Quality control of the data is limited to determining consistency between related fields (such as T-S diagrams) and range checking. The remainder of this paper will describe additional quality control procedures applied to the NODC historical nutrient data by the NODC Ocean Climate Laboratory. This is an ongoing and iterative process which will be updated as more data are incorporated into the files and as a result of knowledge gained by this first pass through these procedures. These methods apply to open ocean waters only and ignore coastal regions.

The additional steps used in the quality control (QC) of historical nutrient data are the following: (1) preliminary QC; (2) range checks on the observed level data; (3) statistical checks on the standard level data; and (4) unrealistic feature check based on the objectively analyzed data fields. Each of these steps will be described in detail. The steps are cumulative: for each step of the QC process, profiles or observations which fail a QC test are flagged and excluded from the next step in the procedure. The flags identify the reason the profile or observation was excluded from further analysis. Rather than delete erroneous or suspicious data, we simply tag them with a flag indicating they Have "failed" some test. Each profile in our database is identified by a unique number, thus comments and discussion about data flagged or otherwise is facilitated. Both the observed level and standard level profile data sets being made available as a result of this project contain flags that indicate the status of various quality control procedures. Appendix A contains a description of the various quality control flags used in this study.

A. Preliminary quality control

Preliminary check involves procedures common to all the SD and SD2 parameters such as a check for duplicate depths, depth inversion checks, and duplicate profile checks. All data sets were checked against themselves and other data sets to eliminate replicate profiles. A replicate profile is defined as a profile which contains exactly the same information as another profile including position, date and parameter values. The criteria for finding replicates was strict so as not to eliminate acceptable data. Two profiles which appear to be duplicates may both bc saved if one profile contains interpolated data while the other does not, or if one profile includes minutes in the latitude and longitude fields while a similar profile canoes not. Approximately 20,000 duplicate profiles were identified in the NODC data base.

A depth inversion error occurs when a reading has a shallower depth than the reading directly above it. A depth duplication is a reading which has the same depth as the reading above it. The second reading is the flagged depth. If, after an inversion or duplication check, the next depth reading is still shallower than the first reading, this and all subsequent depths are flagged. This usually occurs when two or more profiles are entered together with no separating header information. A total of 10,202 profiles were flagged for depth inversions or as depth duplicates.

B. Range check on the observed level data

Range checks screen the data for extreme minimum and maximum values. Coarse ranges were set for the annual (ie. all-seasons) data as a function of depth (depths listed in Table 1) and basin (basins shown in Fig. 2) for each parameter. The following steps were used to set the ranges:

(1) The first step was to examine the frequency distribution of values for each parameter. The observed level data were first converted to the closest standard depth level in order to facilitate the computation of the frequency distributions. The depth range for this conversion is determined as the region three-fourths of the distance between the shallower standard level and the next deeper level. This depth conversion is biased toward deeper values. For example, using standard level 26 (2000 m), the observed depths would fall between 1812.5 m (3/4 of the distance between

levels 25 (1750 m) and 26) and 2125 m (1/4 the distance between levels 26 and 27 (2S00 m)). Initial ranges were set to include values with a frequency greater than 0.5%. This approach leaches to very 4roac1 ranges in surface waters, narrowing down with increasing depths. Broad ranges were set since one set of ranges was used for all seasons. Table 3 shows the percentage of phosphate values in the North Pacific which fall within 15 phosphate class intervals as a function of depth. The shaded area represents the range of acceptable phosphate values in the North Pacific as a function of depth.

(2) Statistical analysis of the data for each depth anti basin was performers to determine the mean and the range of values which fall within one, two, and three standard deviations away from the mean. In most cases, these results were used to set an upper limit of acceptable values.

(3) Comparison of the output from the frequency distribution and statistical analysis to literature values and atlases primarily GEOSECS (Bainbridge, 1977; Craig *et al.*, 1981, Spencer *et al.*, 1982), Southern Ocean Atlas (Gorcion *et al.*, 1982), Wyrtki (1988) and Levitus *et al.* (1993) were used to set the final ranges.

(4) Based on the results from steps 1-3, ranges were set and applied to the observed level data.

The following section will discuss the ranges set for each ocean basin, the location of the outliers, and the number of outliers as a function of depth for each parameter in both the SD and SD2 files. An outlier is defined as an observation or entire profile which is flagged because it failed a particular QC check. This section will be lengthy since most of the observations were flagged by the range check. The defined ranges are for open ocean waters and ignore coastal regions where the nutrient concentrations can greatly exceed concentrations found in open ocean waters. Coastal areas are defined as any one-degree grid point adjacent to a land grid point or any one-Degree grid point which Has a bottom depth of less than 200 m. Unrealistic extreme ranges were set for coastal regions to avoid setting flags to these data. In some areas, the range was not set high enough and data from coastal areas were flagged. In addition, no attempt was made to set realistic ranges for waters below 5500 m depth because of lack of data (see Table 1).

(a) Phosphate

The ranges set for phosphate are presented in Tables 4-7 for each ocean basin as a function of depth. The location of the outliers which result from these range checks are presented in Figs. 4a and 4b for the SD and SD2 file. For the SD file, there are 9,254 profiles which contain observations that (to not fit within the ranges defined, mostly in coastal regions. The SD2 file has 1,913 flagged observations, mostly in coastal areas and the North and Equatorial Atlantic Oceans.

Fig. 5 and Tables 8-11 show the distribution of the outliers as a function of basin and depth. The designation "High" refers to the number of observations which exceed the upper range limit, and "Low" refers to those observations which have lower values than those listed in Tables 4-7. For phosphate, most of the outliers are a result of extreme high values, particularly in the North and

Equatorial Atlantic, the South Pacific and the South Indian Oceans. Most of the high outliers are found in the upper 300 m of the water column in the Atlantic and Pacific Oceans, and the upper 100 m for the Indian Ocean. In contrast, most of the low outliers are found below 400 m except in the Equatorial Pacific Ocean where they are below 200 m.

In addition, for depths below 5500 m, the phosphate upper limit was set at 6.0 µM. There are 118 observations exceeding this value.

(b) Nitrate

The ranges set for nitrate are listed in Tables 12-15 for each ocean basin. Note the minimum value for nitrate was set at 0.01 µM to compensate for the fact that 0.0 appears to have been used as a missing value by many investigators. Setting a minimum value of 0.01 µM also eliminates valid zero surface water values. Procedures to identify valid zero values in the profiles containing nitrate data are underway.

The location of outliers from the nitrate range check is shown in Figs. 6a and 6b for the SD and SD2 files. For the SD file, there are 9,352 profiles containing observations that do not fit within the ranges defined. The SD2 file has 535 profiles containing outliers. Fig. 7 and Tables 16-19 show the distribution of the outliers as a result of setting ranges as a function of basin and depth per basin. The upper range for waters exceeding 5500 m depth was set at 60.0 µM, which results in 54 observations exceeding this value.

Unlike phosphate, most nitrate range outliers are due to the lower limit set, specifically setting the minimum range value to 0.01 µM instead of zero in order to flag missing data values of zero. Tables 16-19 show most "low" outliers are in the upper 50-100 m of the water column, particularly in the North Pacific, Equatorial Indian and South Indian Oceans. Most observations exceeding the high range value are also found in surface waters, particularly in the North and Equatorial Atlantic Oceans.

(c) Silicate

The ranges set for silicate are shown in Tables 20-23 for each ocean basin. The location of outliers which result from the range check is shown in Figs. 8a and 8b for both the SD and SD2 files. For the Station Data file, there are 11,464 profiles containing flagged observations. The SD2 file has 1,502 profiles containing outliers. Most of these outliers are located around Australia and Japan. Fig. 9 and Tables 24-27 show the distribution of the outliers as a function of basin and depth. Most of the outliers are values which exceed the limit set for silicate in all ocean basins. The high outliers are distributed with depth. The low outliers are found at depths where the minimum range is no longer a zero value.

The deep water (> 5500 m depth) upper limit for silicate was set at 150 µM. There are 119 observations which exceed this value.

C. Interpolation from observed to standard depth levels

Prior to the next step in the quality control, the data are interpolated from observed levels to standard levels. The interpolation scheme used is a modification from that described by Reiniger and Ross (1968) and noted by UNESCO (1991) as being in common usage. Their scheme uses four observed values surrounding the standard level in question, the two closest shallower values and the two closest deeper values. The closest shallower and deep values ("inside" values) and the two farthest shallow and deep values ("outside" values) must be within the depth difference criteria shown in Table 28. The first set of depths in this table is the maximum distance between the closest or "inside" observed reading depth. The second set of depths applies to the maximum distances to the two observed levels further from the standard level in question. This interpolation scheme has the advantage over three point Lagrangian interpolation of being less susceptible to extremes when a large gradient is encountered since two separate three-point Lagrangian interpolations are averaged and then fit to a reference curve.

If all the above criteria are met, the standard depth value is set by the Reiniger and Ross (1968) interpolation. If there are not enough surrounding values within acceptable distances, three point Lagrangian interpolation is performed on the value above and two values below the level in question or on the two values above and one value below:

$$X(z) = x_1 \frac{(z-z_2)(z-z_3)}{(z_1-z_2)(z_1-z_3)} + x_2 \frac{(z-z_1)(z-z_3)}{(z_2-z_1)(z_2-z_3)} + x_3 \frac{(z-z_1)(z-z_2)}{(z_3-z_1)(z_3-z_2)} \qquad (1)$$

where z_1 ,z_2, and z_3 are the shallowest, middle and deepest observed depths respectively, z is the desired level for interpolation, and x_1 ,x_2, and x_3 are the values associated with the shallowest, middle and deepest depths; X(z) is the interpolated value.

If there are insufficient data points to perform the above calculations, straight linear interpolation is used:

$$X(z) = x_1 + \frac{(z-z_1)}{(z_2-z_1)} * (x_2-x_1) \qquad (2)$$

where x_1 and x_2 are the observed data values, z_1 and z_2 are the shallowest and deepest depths, z is the desired level for interpolation and X(z) is the desired interpolated value.

Modifications to the Reiniger and Ross (1968) method are the following:

1. If the Reiniger and Ross interpolated value does not fall between the observed values directly above and below it, linear interpolation is substituted.
2. If any value is recorded within 5 meters of the surface, this value is directly used as the

surface value.

Some observed level data were "lost" in the interpolation process because they were too far from a standard level (and therefore not used), or there were other closer observations available. A summary of the number of observations which met the criteria for the different interpolation methods is presented in Table 29. Direct substitution and the Reiniger and Ross interpolation account for most of the standard level values.

D. Statistical analysis of data at standard depth levels

Once observed level data were interpolated to standard levels, the two data files, SD and SD2, were merged and statistical checks were performed to flag data which exceeded the standard deviation criteria. All non-flagged data were first averaged by five-degree-squares to produce the number of observations, mean, and standard deviation for each square. Each five degree square box was designated coastal, near coastal, or open ocean, depending on the number of one-degree by one-degree latitude-longitude gridboxes in the five-degree box which were land (0 m depth) areas. Profiles were flagged if: (a) a five-degree square containing a land point exceeded 5 standard deviations in the upper 50 m; (b) near-coastal regions with values exceeding 4 standard deviations in the upper 50 m; (c) values exceeding three standard deviations for all other data 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, then 4 standard deviations were used. The reason for varying the number of standard deviations allowed is the high variability in shallow coastal areas due to river runoff, upwelling and other factors. High variability within a five-degree box near the ocean bottom can occur if the five-degree square box contains portions 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 grid box. If more than two observations in a profile exceeded the selected criteria, the profile was flagged and not included in further analysis.

The standard deviation check was applied twice to the data and then new five-degree square statistics were computed to produce a new "clean" data set. Results from the standard deviation check show 5764 phosphate profiles containing outliers, 2105 nitrate profiles with outliers and 346S silicate outliers. The number of outliers decreases rapidly as a function of depth. Figures 10-15 show the location of profiles which were flagged during the statistical check for the SB and SD2 files and the distribution of these outliers with depth.

Five-degree square statistics are an additional product from this analysis. The five-degree statistics available are the number of observations, mean, and root-mean-square deviation.

K. Objective analysis

Following the statistical check, data were averaged by one-degree squares for input to the objective analysis. The objective analysis is described by Levitus and Boyer (1994) and Conkright *et al* (1994). After the initial objective analyses was computed for each standard level, there were still erroneous values which resulted in rapid concentration changes within an area appearing as a "bull’s-eye" or some other unrealistic feature. Figure 16a shows an unrealistic feature ("bullseye") still present after the range and statistical checks (Figure 16b shows the same figure after the unrealistic features have been flagged). These features occur because of the difficulty in identifying non-representative values in data sparse areas. Figures 17-19 show the location of data which were flagged due to unrealistic or erroneous values found in contour plots of the initial objectively analyzed fields. All these data were identified by investigating suspicious features and identifying the profile or individual data points which created each unrealistic feature. In some cases, entire cruises were flagged. Tables 30 and 31 list the cruises which were flagged as containing unrepresentative data for nitrate and silicate respectively. No cruises were flagged for phosphate. In addition, no cruises were flagged in the SD2 file.

SUMMARY AND FUTURE WORK

Tables 32, 33 and 34 list the total number of profiles containing flagged observations for each QC step. The summary listed in these figures does not include the outliers from the preliminary check (duplicates, depth errors, position errors). Most of the observations were flagged during the range check. Table 35 is a summary of the number of profiles containing flagged observations from the range check of phosphate, nitrate and silicate as a function of ocean basin. The majority of the outliers for phosphate and silicate were observations exceeding the ranges set, unlike nitrate where the largest number of outliers were due to zero values. As previously noted, the high percentage of low outliers for nitrate is due to using 0.01 µM as a lower limit to avoid using missing values of zero as data. One reason for the large number of range outliers is that the ranges set must include seasonal and geographical variability.

Future work will include the following:
(1) identify profiles where zero is used as a missing value and conversion to -99.999 as a new missing value - this work is already in progress,
(2) develop ranges for each season at each basin as a function of depth,
(3) geographic expansion of the range definition process to include coastal regions and some of the major inland seas such as the Mediterranean, Baltic and Black Sea,
(4) improve the vertical interpolation scheme by developing criteria for the depth of the "inner" points based on the geographical location of the profile as well as the time of year,
(5) incorporate feedback from data managers and scientists who have utilized the data sets distributed by the NODC and have identified additional problems with the data.

The flagged observed and standard level data used in this study and in the preparation of the World Ocean Atlas 1994, Volume 1: Nutrients (Conkright *et al.,* 1994) are available on CD-ROM. Appendix 1 is a description of the flags used to identify erroneous data in the SD and SD2 files. Appendix 2 is a sample program which reads the CD-ROM data. A sample output of the flagged observed level nutrient data is shown in Appendix 3.

In addition to the observed and standard level data, one-degree latitude-longitude objective analyzed values for phosphate, nitrate and silicate and five-degree square statistics will be available on CD-ROM. The one-degree and five-degree horizontal co-ordinate systems used for the analyzed fields are shown in Appendices 4 and 5. The data on the CD-ROM are sorted using the geographic grid numbering system of World Meteorological Organization (WMO) where ten-degree by ten-degree latitude-longitude squares are assigned a unique number (WMO squares are shown in Appendix 6).

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APPENDIX 1. 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 > 0.3º/meter
3 - temperature gradient of magnitude > 0.7º/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 2. FORTRAN PROGRAM TO READ AND WRITE OBSERVED LEVEL AND STANDARD LEVEL VERTICAL PROFILE DATA

```
      program OCLdemo

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

ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
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 <town 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       ctime - 6 characters representing GM time
c               in hours, r3own 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       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 maxleve1=6000, maxparm=15, kdim=33 parameter bmiss=-
      1.E10, amiss=-99.99
c
      character*2 cc
      character*6 ctime
      character*80 nfile, ifile
      character*4 param(9)
c
      dimension data(maxlevel,maxparm), depth(maxlevel),dz(kdim) dimension
      ierror(maxparm),iderror(maxleve1,0: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','02','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,ctime,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.l.and.ij.eq.1) then
          do 60 i=l,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,
      * ctime,jjx,numlevels,(ierror(np),np= 1,nparm)
799 format('cc',3x,'cruise',4x,'lat',Sx,'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=l,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
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      subroutine OCLread(cc,icruise,rlat,rlon,iyear,month,
     *  iday,ctime,nprofile,numlevels,isoor,nparm,newfile,data,
     *  depth,maxlevels,maxparm,ierror,iderror,ip2,bmiss,ieof)
c
c subroutine to read OCL ascii format
c
c
      parameter amiss=-99.99
      character cc*2, cholder*80, ctime*6
c
      dimension data(maxlevels,maxparm),iderror(maxlevels,O:maxparm) dimension
      depth(maxlevels),ierror(maxparm),ip2(0:maxparm)
c
c read in header
      if ( ieof .1t. 1 ) then
       read(newfile,800,end=4) cc,icruise,rlat,rlon,iyear,month,iday,
      *  ctime,nprofile,numlevels,isoor,nparm,(ip2(i),ierror(ip2(i)),
      *  i=l,nparm)
c
800     format(a2,i5,f7.3,f8.3,i4,i2,i2,a6,i8,i3,il,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 1=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
          unread=0
          idp=1
         endif
         endif
c
        if ( iend .1t. 1 ) then
c
         if ( idp .eq. 1 .and. isoor .eq. 0 ) then
         read(cholder(m2:m2+7),'(f7.2,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
c
      return
c
4        ieof = 3.
         return
c
      end
```

APPENDIX 3. SAMPLE OUTPUT OF OBSERVED LEVEL NUTRIENT DATA

cc	cruise	lat	long	year	mm	dd	GMT	profile	depths	flag
46	0	64.67	-27.60	1965	5	9	20.00	28333	14	0

Depth	F	PO4	F	Si	F	NO3	F
0.	0	-99.99	0	4.90	0	11.20	0
10.	0	0.78	0	6.10	0	11.20	0
20.	0	0.77	0	6.10	0	11.60	0
30.	0	0.88	0	6.30	0	11.70	0
50.	0	0.77	0	6.10	0	11.60	0
75.	0	0.86	0	6.30	0	11.30	0
100.	0	0.79	0	6.30	0	12.00	0
200.	0	0.93	0	6.10	0	12.00	0
300.	0	0.91	0	6.50	0	11.90	0
400.	0	0.82	0	6.80	0	11.70	0
500.	0	-99.99	0	-99.99	0	-99.99	0
500.	1	0.96	0	5.90	0	12.30	0
600.	0	0.97	0	7.80	0	12.50	0
690.	0	-99.99	0	6.10	0	12.90	0

Appendix 4. One-degree horizontal co-ordinate system of the analyzed fields

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

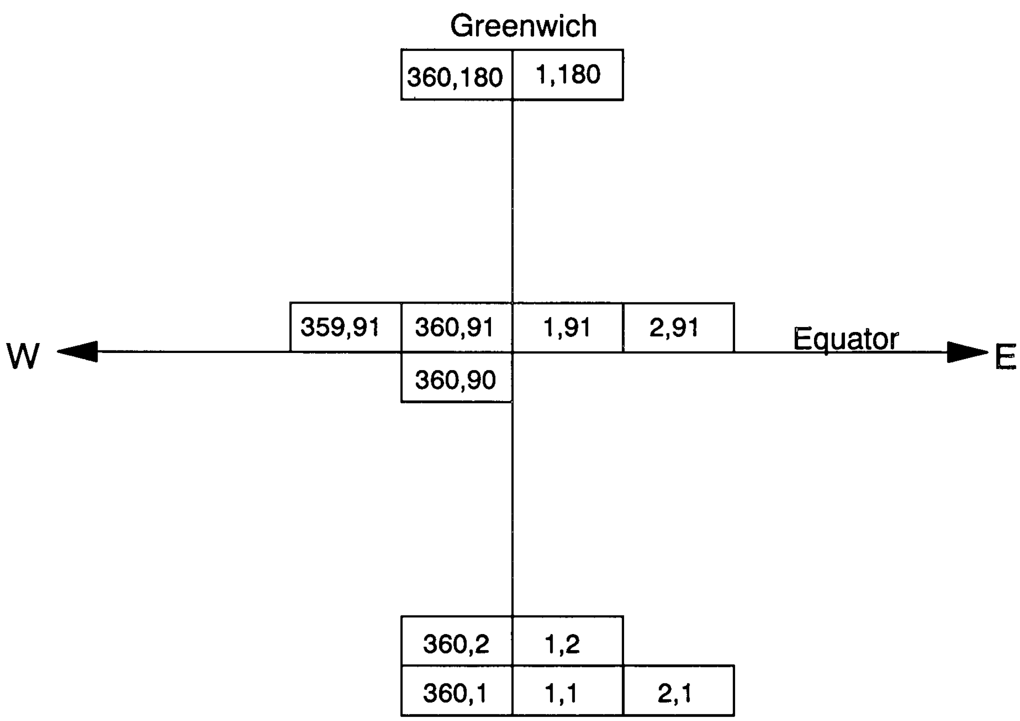
Longitude denoted by the variable "i", varies from 1 at 0.5 º E to 360 at 0.5ºW

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

The point F(1,1) is the value at 0.5 ºE, 89.5ºW

The point F(218,20) is the value at 142.5ºW, 70.5ºS

The point F(360,91) is the value at 0.5ºW, 0.5ºN

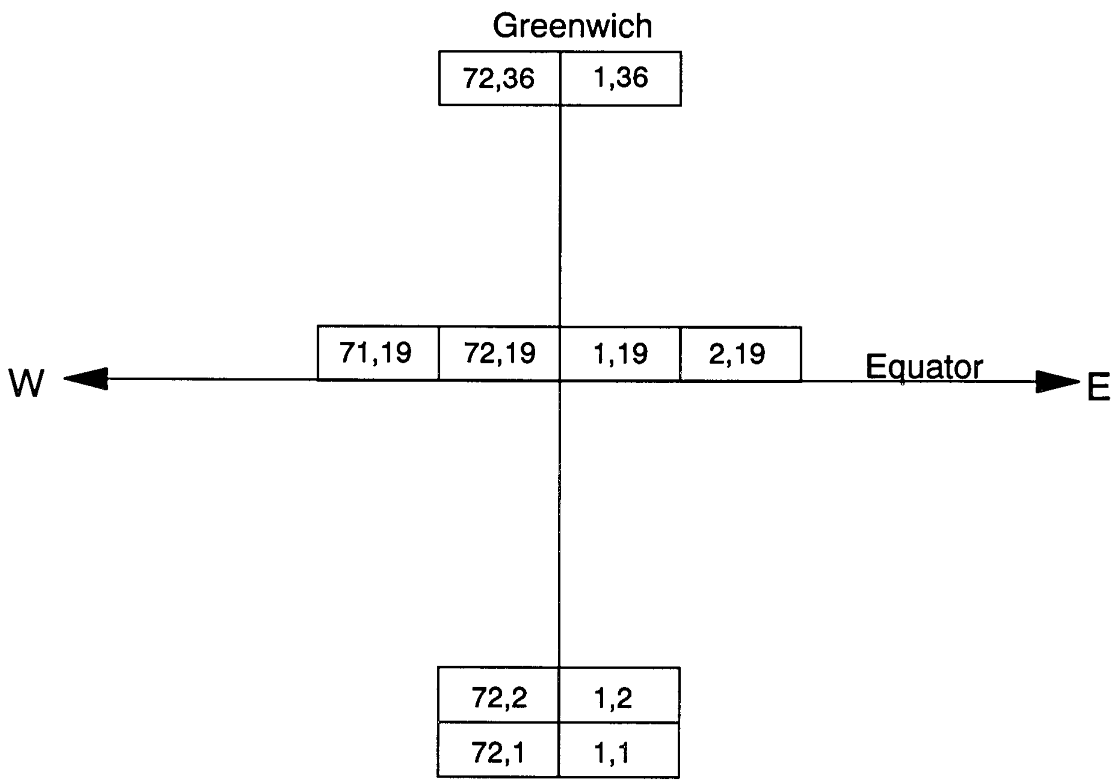


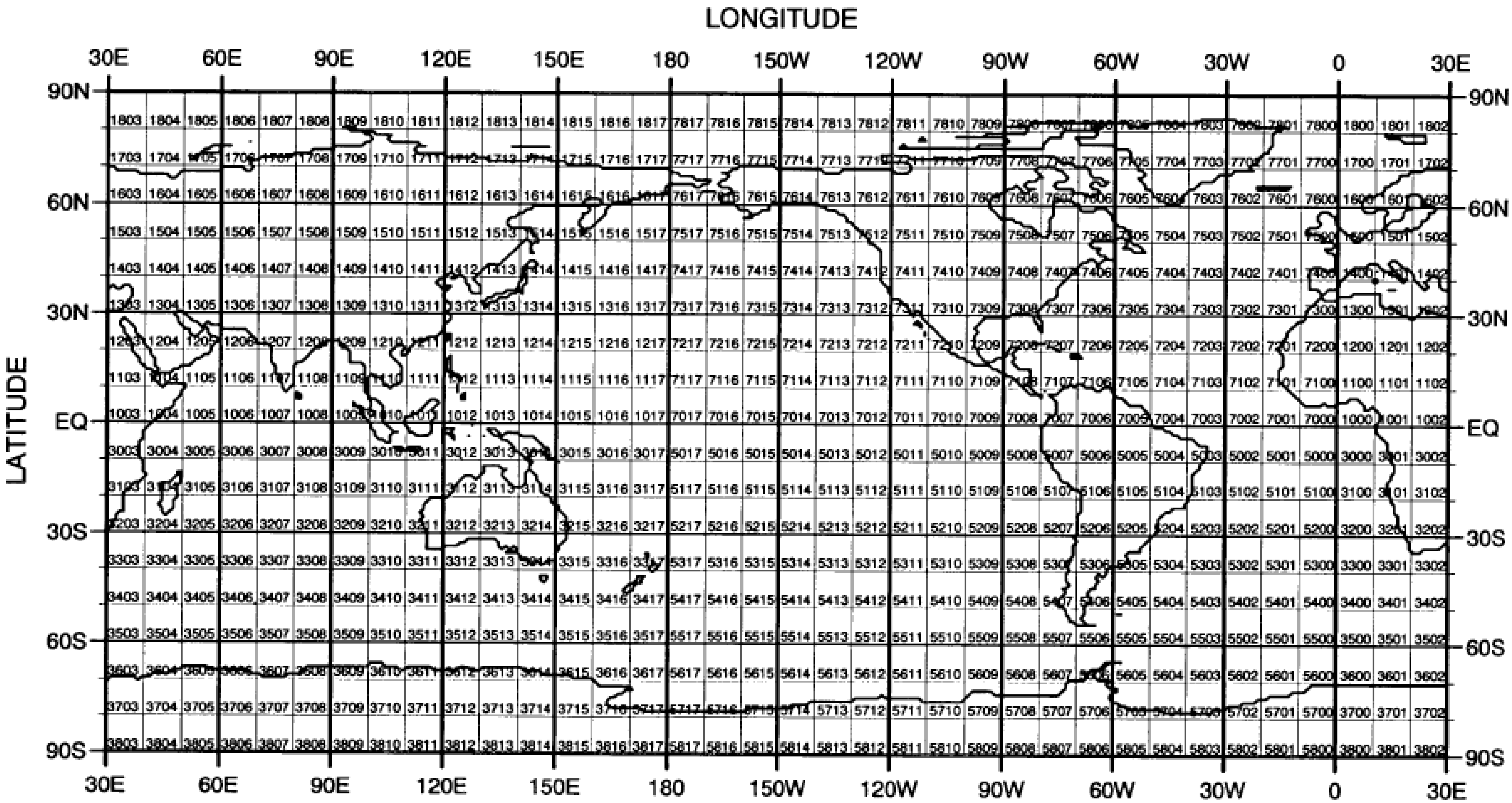
Appendix 5. Five-degree horizontal co-ordinate system of the analyzed fields

Each element of 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 º E to 72 at 2.5ºW

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





Appendix 6. WMO SQUARE CHART

Table 1. Distribution with depth of phosphate, nitrate and silicate observations.

Depth	Phosphate	Nitrate	Silicate
0	173484	68007	102890
10	156184	58789	88090
20	153475	61565	90865
30	144104	54897	82806
50	141130	53233	81579
75	116268	42701	65280
100	109022	41439	63678
125	93489	35670	54611
150	91286	35140	54410
200	81583	32028	47732
250	78056	29152	45471
300	75242	27988	42831
400	72411	26119	41625
500	64095	24395	37068
600	57649	19379	33317
700	53901	17684	31518
800	52163	17247	30347
900	50185	16152	29543
1000	47346	15403	27823
1100	39978	13200	23562
1200	36291	12343	21800
1300	32497	11167	19979
1400	29814	9949	18772
1500	26435	9238	16688
1750	21629	7765	13187
2000	18108	6679	11342
2500	11872	5712	8907
3000	9038	4424	6989
3500	7392	3618	5669
4000	5175	2937	4304
4500	3254	2036	2951
5000	1627	1096	1465
5500	562	397	497

Table 2. Number of phosphate, nitrate and silicate profiles for each season in the SD and SD2 files

Season	Phosphate		Nitrate		Silicate	
	SD	SD2	SD	SD2	SD	SD2
Winter (Jan-Mar)	35411	7442	15301	2518	20248	5199
Spring (Apr-Jun)	43927	7169	18576	4021	24756	6619
Summer (Jul-Sep)	47794	6707	18429	2405	27285	5196
Fall (Oct-Dec)	29061	6642	12123	2030	16425	4685
Total profiles/file	156193	27960	64429	10974	88714	21699
Total Profiles	184153		75403		110413	

Table 3. Frequency distribution (in percent) of phosphate values in the North Pacific Ocean

Depth	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*	15*
0	44.6	25.4	12.8	5.8	5.8	2.2	2.3	1.6	1.7	0.1	0.0	0.0	0.0	0.0	0.0
10	44.3	25.2	12.9	5.8	5.8	2.4	2.2	1.6	2.0	0.1	0.0	0.0	0.0	0.0	0.0
20	43.0	24.7	12.8	6.1	6.1	2.7	2.4	2.1	2.0	0.2	0.0	0.1	0.0	0.0	0.0
30	40.4	24.1	13.0	6.2	6.2	3.2	2.9	2.5	3.0	0.6	0.1	0.0	0.0	0.0	0.0
50	35.4	21.1	12.8	7.6	7.6	3.7	3.4	3.1	5.4	1.8	0.2	0.0	0.0	0.0	0.0
75	30.2	17.4	11.8	8.2	8.2	5.8	4.5	3.8	6.6	4.2	0.7	0.0	0.0	0.0	0.0
100	26.5	15.0	10.1	8.1	8.1	6.0	5.5	4.7	8.8	6.6	1.9	0.2	0.0	0.0	0.0
125	21.9	14.9	7.6	7.1	7.1	6.4	6.1	5.5	10.6	8.9	4.1	0.5	0.0	0.0	0.0
150	17.3	16.8	6.9	5.6	5.6	5.9	6.2	5.7	11.6	10.6	6.1	1.2	0.1	0.0	0.0
200	8.9	18.6	8.6	4.8	4.8	4.4	5.5	5.6	13.2	13.0	9.5	2.6	0.6	0.0	0.0
250	4.8	13.9	11.5	5.2	5.2	4.4	5.1	5.5	10.2	15.5	13.7	4.8	1.0	0.0	0.0
300	2.7	8.0	11.9	7.0	7.0	4.0	4.4	5.7	9.6	13.8	18.7	7.8	1.7	0.0	0.0
400	1.2	2.7	5.3	8.0	8.0	4.7	4.1	4.9	11.2	8.8	18.0	20.5	3.3	0.1	0.0
500	1.0	1.3	1.2	2.8	2.8	6.5	6.1	5.2	13.2	8.9	13.6	27.5	6.9	0.3	0.0
600	1.2	1.2	0.5	0.5	0.5	3.4	5.4	6.9	17.8	13.3	16.2	20.7	10.7	0.4	0.0
700	1.6	1.6	0.5	0.4	0.4	0.8	1.5	3.3	14.3	20.1	21.8	22.0	11.5	0.4	0.0
800	2.1	2.0	0.5	0.7	0.7	0.4	0.8	0.8	5.4	14.7	28.1	30.2	13.3	0.5	0.0
900	0.9	0.8	0.3	0.1	0.1	0.3	0.3	0.5	4.5	7.4	22.3	38.1	23.0	1.4	0.0
1000	0.8	0.8	0.3	0.1	0.1	0.3	0.3	0.5	4.1	5.4	16.0	44.5	25.4	1.2	0.0
1100	0.7	0.7	0.3	0.1	0.1	0.2	0.2	0.3	3.8	4.9	12.2	51.2	24.5	0.8	0.0
1200	1.1	0.9	0.3	0.2	0.2	0.3	0.1	0.2	3.4	4.7	11.7	54.4	21.9	0.6	0.0
1300	0.9	0.6	0.3	0.1	0.1	0.3	0.1	0.1	4.1	4.8	12.7	57.6	17.5	0.6	0.0
1400	1.1	1.1	0.3	0.2	0.2	0.2	0.1	0.4	2.8	4.4	14.7	60.3	14.0	0.4	0.0
1500	1.6	1.5	0.7	0.2	0.2	0.4	0.2	0.1	2.1	3.6	16.1	62.6	10.8	0.0	0.0
1750	2.7	2.5	0.7	0.1	0.1	0.2	0.1	0.1	2.0	1.1	19.6	65.3	5.4	0.0	0.0
2000	1.0	0.9	0.2	0.1	0.1	0.3	0.5	0.4	4.7	7.2	26.7	53.2	4.8	0.0	0.0
2500	1.2	1.0	0.3	0.1	0.1	0.4	0.5	0.5	4.8	8.0	46.8	34.8	1.6	0.0	0.0
3000	1.5	1.0	0.4	0.2	0.2	0.4	0.4	0.6	4.2	8.2	66.8	15.6	0.5	0.0	0.0
3500	1.8	1.0	0.5	0.1	0.1	0.5	0.3	0.7	2.9	7.2	75.7	8.7	0.2	0.0	0.0
4000	1.9	1.0	0.4	0.2	0.2	0.6	0.8	0.8	3.2	8.5	77.4	4.7	0.0	0.0	0.0
4500	0.5	0.7	0.0	0.0	0.0	0.9	0.6	1.3	3.0	12.3	76.7	4.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.1	0.1	0.7	0.3	1.0	4.0	20.5	70.2	2.4	0.0	0.1	0.0
5500	0.0	0.3	0.0	0.3	0.3	0.3	0.0	0.7	2.6	26.9	66.9	1.3	0.0	0.0	0.3

1 = 0.0-0.2 2 = 0.2-0.4 3 = 0.4-0.6 4 = 0.6-0.8 5 = 0.8-1.0
6 = 1.0-1.2 7 = 1.2-1.4 8 = 1.4-1.6 9 = 1.6-2.0 10 = 2.0-2.4
11 = 2.4-2.8 12 = 2.8-3.2 13 = 3.2-3.6 14 = 3.6-4.0 15 = >4.0

Table 4: Phosphate 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	1.4	0.0	1.0	0.0	2.0
10	0.0	1.4	0.0	1.0	0.0	2.0
20	0.0	1.4	0.0	1.2	0.0	2.0
30	0.0	1.4	0.0	1.4	0.0	2.0
50	0.0	2.0	0.0	2.0	0.0	2.0
75	0.0	2.0	0.0	2.4	0.0	2.4
100	0.0	2.0	0.0	2.4	0.0	2.4
125	0.0	2.0	0.0	2.8	0.0	2.4
150	0.0	2.0	0.0	2.8	0.0	2.4
200	0.0	2.4	0.0	2.8	0.0	2.8
250	0.0	2.4	0.0	3.2	0.0	2.8
300	0.0	2.4	0.0	3.2	0.0	2.8
400	0.0	3.2	0.0	3.6	0.2	3.2
500	0.0	3.2	0.0	3.6	0.2	3.2
600	0.0	3.2	0.0	3.6	0.2	3.2
700	0.2	3.2	0.2	3.6	0.2	3.2
800	0.2	3.2	0.2	3.6	0.2	3.2
900	0.2	3.6	0.3	3.6	0.2	3.2
1000	0.2	3.6	0.3	3.6	0.4	3.2
1100	0.2	3.6	0.3	3.6	0.4	3.2
1200	0.2	3.6	0.3	3.6	0.4	3.2
1300	0.2	3.6	0.3	3.6	0.4	3.2
1400	0.2	3.6	0.6	3.2	0.4	3.2
1500	0.2	3.6	0.6	3.2	0.4	3.6
1750	0.2	3.6	0.6	3.2	0.4	3.6
2000	0.2	3.6	0.3	3.2	0.4	3.6
2500	0.2	3.4	0.3	3.2	0.4	3.6
3000	0.2	3.4	0.3	3.2	0.4	3.6
3500	0.2	3.4	0.3	3.2	0.6	3.2
4000	0.4	3.2	0.5	3.2	0.6	3.2
4500	0.4	3.2	0.6	2.8	0.6	3.2
5000	0.4	2.8	0.6	2.8	0.8	2.8
5500	0.4	2.8	0.6	2.8	0.8	2.8

Table 5. Phosphate 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	2.0	0.0	2.0	0.0	1.6
10	0.0	2.0	0.0	2.0	0.0	1.6
20	0.0	2.0	0.0	2.0	0.0	1.6
30	0.0	2.0	0.0	2.0	0.0	1.6
50	0.0	2.4	0.0	2.4	0.0	2.0
75	0.0	2.8	0.0	2.8	0.0	3.2
100	0.0	2.8	0.0	2.8	0.0	3.2
125	0.0	3.2	0.0	3.2	0.0	3.2
150	0.0	3.2	0.0	3.2	0.0	3.2
200	0.0	3.6	0.2	3.2	0.0	3.2
250	0.0	3.6	0.4	3.2	0.0	3.2
300	0.0	3.6	0.6	3.2	0.0	3.2
400	0.0	3.6	0.6	3.6	0.4	3.6
500	0.2	3.6	0.8	3.6	0.4	3.6
600	0.2	3.6	0.8	3.8	0.8	3.8
700	0.8	3.6	0.8	3.8	0.8	3.8
800	0.8	3.8	0.8	3.8	0.8	3.8
900	0.8	3.8	0.8	3.8	0.8	3.8
1000	0.8	3.8	0.8	3.8	0.8	3.8
1100	0.8	3.8	0.8	3.8	0.8	3.8
1200	0.8	3.8	0.8	3.8	0.8	3.6
1300	0.8	3.8	0.8	3.8	0.8	3.6
1400	0.8	3.6	0.8	3.8	0.8	3.6
1500	0.8	3.6	0.8	3.6	0.8	3.6
1750	0.8	3.6	0.8	3.6	0.8	3.6
2000	0.8	3.6	0.8	3.6	0.8	3.6
2500	0.8	3.6	0.8	3.6	0.8	3.6
3000	0.8	3.6	0.8	3.6	0.8	3.2
3500	0.8	3.2	0.8	3.2	0.8	3.2
4000	0.8	3.2	0.8	3.2	0.8	3.2
4500	0.8	3.2	0.8	3.2	0.8	3.2
5000	0.8	3.2	0.8	3.2	0.8	3.2
5500	0.8	3.2	0.8	3.2	0.8	3.2

Table 6. Phosphate ranges in the Indian Ocean as a function of depth.

Depth	North Indian		Eq. Indian		South Indian	
	Low	High	Low	High	Low	High
0	0.0	1.4	0.0	1.0	0.0	2.0
10	0.0	1.4	0.0	1.0	0.0	2.0
20	0.0	1.4	0.0	1.0	0.0	2.0
30	0.0	1.6	0.0	1.0	0.0	2.0
50	0.0	2.0	0.0	1.2	0.0	2.0
75	0.0	2.8	0.0	2.0	0.0	2.0
100	0.0	3.6	0.0	2.4	0.0	2.0
125	0.0	3.6	0.0	2.4	0.0	2.4
150	0.0	3.6	0.0	2.8	0.0	2.4
200	0.6	3.6	0.4	2.8	0.0	2.4
250	0.6	3.6	0.4	2.8	0.0	2.4
300	0.6	3.6	0.4	2.8	0.0	2.8
400	0.6	3.6	0.4	3.2	0.0	2.8
500	0.8	3.8	0.4	3.2	0.0	2.8
600	0.8	3.8	0.4	3.6	0.0	3.2
700	0.8	3.8	0.4	3.6	0.2	3.2
800	0.8	3.8	0.4	3.8	0.4	3.2
900	0.8	3.8	0.4	3.8	0.4	3.2
1000	0.8	3.8	0.4	3.8	0.4	3.2
1100	0.8	3.8	0.6	3.8	0.4	3.2
1200	0.8	3.8	0.6	3.8	0.4	3.2
1300	0.8	3.8	0.8	3.8	0.4	3.2
1400	0.8	3.8	0.8	3.6	0.4	3.2
1500	0.8	3.8	0.8	3.6	0.4	3.2
1750	0.8	3.8	0.8	3.6	0.4	3.2
2000	0.8	3.8	0.8	3.6	0.4	3.2
2500	0.6	3.8	0.8	3.6	0.4	3.2
3000	0.6	3.6	0.8	3.2	0.4	3.2
3500	0.6	3.6	0.8	32	0.4	3.2
4000	0.6	2.8	0.8	3.2	0.4	3.2
4500	0.6	2.8	0.8	3.2	0.4	3.2
5000	0.6	2.8	0.8	3.2	0.8	3.2
5500	0.6	2.8	0.8	3.2	0.8	3.2

Table 7. Phosphate ranges for the Southern and Arctic Oceans as a function of depth.

Depth	Southern Ocean		Arctic 0cean	
	Low	High	Low	High
0	0.2	2.8	0.0	1.4
10	0.2	2.8	0.0	2.0
20	0.2	2.8	0.0	2.4
30	0.2	2.8	0.0	2.8
50	0.2	2.8	0.0	2.8
75	0.2	2.8	0.0	2.8
100	0.2	3.2	0.0	2.8
125	0.4	3.2	0.0	2.8
150	0.4	3.2	0.0	2.8
200	0.4	3.2	0.0	2.8
250	0.6	3.2	0.0	2.8
300	0.6	3.2	0.0	2.8
400	0.6	3.2	0.0	2.8
500	0.6	3.2	0.0	2.8
600	0.6	3.2	0.0	3.2
700	0.6	3.2	0.2	3.2
800	0.6	3.2	0.4	3.8
900	0.6	3.2	0.4	3.8
1000	0.6	3.2	0.4	3.8
1100	0.6	3.2	0.4	3.8
1200	0.6	3.2	0.4	3.8
1300	0.6	3.2	0.4	3.8
1400	0.8	3.2	0.4	3.8
1500	0.8	3.2	0.4	3.8
1750	0.8	3.2	0.4	3.8
2000	0.8	3.2	0.4	3.8
2500	0.8	3.2	0.4	3.8
3000	0.8	3.2	0.6	3.6
3500	0.8	3.2	0.6	3.6
4000	0.8	3.2	0.6	3.2
4500	0.8	3.2	0.6	2.8
5000	0.8	3.2	0.6	2.8
5500	0.8	2.8	0.6	2.8

Table 8. Number of phosphate range outliers as a function of depth in the Atlantic Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Atlantic			Equatorial Atlantic			South Atlantic		
Depth	N	High	Low	N	High	Low	N	High	Low
0	18376	632	0	4284	246	0	3,511	29	0
10	13835	523	0	3026	175	0	2,274	23	0
20	12073	515	0	2972	128	0	2,655	32	0
30	11328	519	1	3828	120	0	2,790	21	0
50	17006	287	0	4639	55	0	3,410	43	0
75	13310	268	0	4429	44	0	2,282	10	0
100	15664	245	0	4095	55	0	2,700	15	0
125	5300	107	0	1785	18	0	770	3	0
150	12030	238	0	3395	39	0	2 130	16	0
200	11910	129	0	3602	42	0	2,824	9	0
250	8517	107	0	2108	15	0	1,489	1	0
300	12009	173	0	3455	34	0	2,337	13	0
400	12048	20	0	3512	25	0	2,850	6	32
500	11491	23	0	3200	22	0	2,287	12	19
600	6939	14	0	2210	34	0	2,249	13	14
700	4132	15	207	1451	24	9	1,688	13	21
800	8785	48	277	1818	31	18	1,742	10	24
900	3491	21	126	1052	19	6	1,204	6	11
1000	8142	30	241	1541	14	13	1,500	11	32
1100	2356	23	71	866	9	7	911	11	13
1200	3890	20	151	910	3	12	1,038	7	26
1300	1603	9	51	519	0	6	642	2	14
1400	1977	4	43	633	4	12	845	3	10
1500	5303	22	154	1147	6	41	1,322	2	20
1750	2992	1	56	817	3	11	1,111	1	5
2000	6589	1	139	1243	3	14	1,644	0	15
2500	3433	2	44	880	1	11	1,758	1	2
3000	2373	4	35	724	1	7	1,551	0	2
3500	1675	0	26	587	2	3	1,347	3	7
4000	1399	3	31	521	8	2	1,106	0	3
4500	1129	4	13	385	10	0	803	0	4
5000	733	3	7	205	4	0	484	1	0
5500	220	5	0	74	1	0	164	0	0

Table 9. Number of phosphate range outliers as a function of depth in the Pacific Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Pacific			Equatorial Pacific			South Pacific		
Depth	N	High	Low	N	High	Low	N	High	Low
0	24330	300	0	6439	118	0	5,033	471	0
10	20273	252	0	4325	88	0	2,795	427	0
20	17498	254	0	4598	109	0	3,742	444	0
30	17860	278	0	3806	128	0	2,623	434	0
50	25192	160	0	6305	76	0	4,345	326	0
75	22379	57	0	6026	23	0	3,592	7	0
100	22754	96	0	6487	26	0	3,787	16	0
125	13424	19	0	4923	3	0	1,670	3	0
150	22068	76	0	7916	6	0	3,569	17	0
200	23285	34	0	8129	8	120	3,940	10	0
250	14065	17	0	6609	6	90	2,345	Q	0
300	19817	37	0	7071	22	211	3,677	20	0
400	18895	67	0	6074	8	152	2,828	6	268
500	18270	49	199	4792	14	164	2,617	11	232
600	14243	53	104	3008	6	90	1,662	3	210
700	9035	31	157	1856	11	66	1,707	5	171
800	10777	66	237	2102	15	60	1,402	2	173
900	6828	48	63	1640	8	33	1,326	5	95
1000	9010	102	217	1901	14	76	1,363	2	161
1100	5176	58	65	1207	10	30	1,088	10	82
1200	6532	62	133	1097	4	47	954	7	123
1300	3145	30	44	703	4	28	754	0	49
1400	2852	26	47	533	2	17	455	0	46
1500	4807	30	145	943	8	44	1,057	4	112
1750	3719	43	59	618	9	20	584	0	41
2000	4755	49	135	1087	10	45	1,069	2	71
2500	4188	13	80	1030	6	33	1,077	0	31
3000	3745	9	80	832	6	35	957	1	12
3500	3033	28	56	639	3	32	820	1	16
4000	2432	12	37	513	2	10	643	0	16
4500	1776	9	23	320	0	8	433	0	8
5000	1313	8	20	214	0	1	239	0	1
5500	695	3	11	78	0	0	80	0	0

Table 10. Number of phosphate range outliers as a function of depth in the Indian Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Indian			Equatorial Indian			South Indian		
Depth	N	High	Low	N	High	Low	N	High	Low
0	504	7	0	1957	84	0	4 183	150	0
10	247	0	0	1127	31	0	2,347	109	0
20	418	5	0	1372	41	0	3,407	122	1
30	285	5	0	1208	35	0	2,337	108	1
50	498	10	0	1871	49	0	3,869	145	1
75	458	4	0	2067	16	0	3,208	120	0
100	472	1	0	2110	3	0	3,276	116	0
125	191	0	0	1283	3	0	1,276	5	0
150	463	1	0	1944	3	0	2,824	13	0
200	455	5	4	1924	6	49	2,996	23	0
250	205	0	2	1256	4	19	1,487	7	0
300	433	1	0	1674	11	28	2,657	2	0
400	438	2	2	1667	5	14	2,132	4	0
500	411	5	1	1553	15	11	2,115	5	0
600	282	1	0	1109	4	11	1,363	0	0
700	181	2	0	726	4	12	1,228	2	59
800	276	0	1	953	2	8	1,237	2	80
900	148	2	0	476	2	8	1,031	3	58
1000	306	6	1	998	7	6	1,196	7	63
1100	91	5	0	439	4	6	850	2	48
1200	146	3	0	585	1	6	726	3	35
1300	67	2	0	345	2	4	797	2	39
1400	85	1	0	272	1	4	566	9	28
1500	184	8	0	553	7	6	1,006	5	23
1750	164	6	0	458	2	2	603	2	13
2000	217	1	0	719	3	5	1,145	3	34
2500	176	3	1	688	1	7	994	2	26
3000	148	1	1	537	9	6	820	2	27
3500	73	0	0	373	4	3	609	1	15
4000	46	9	0	368	7	4	541	1	6
4500	4	0	0	209	8	3	356	0	4
5000	1	0	0	65	1	3	174	0	7
5500	0	0	0	10	0	1	40	0	0

Table 11. Number of phosphate range outliers as a function of depth in the Southern and Arctic Oceans(N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	Southern Ocean			Arctic Ocean		
	N	High	Low	N	High	Low
0	4035	9	16	10904	225	0
10	3024	10	14	8383	117	0
20	3023	12	11	9803	93	0
30	3387	4	5	5497	28	0
50	4721	14	14	9528	15	0
75	3389	14	12	5546	7	0
100	3407	0	12	8054	8	0
125	956	1	5	2109	4	0
150	3145	0	10	4299	8	0
200	3302	6	15	5924	11	0
250	1374	1	12	2740	5	0
300	2945	8	26	4486	5	0
400	2961	9	18	3021	0	0
500	1961	7	19	3016	3	0
600	2071	7	8	1807	0	0
700	1162	1	17	798	1	24
800	1815	5	10	2154	0	68
900	810	3	4	569	0	45
1000	1778	2	12	2003	0	61
1100	683	2	4	360	0	39
1200	839	2	7	662	0	47
1300	511	2	3	274	0	29
1400	633	1	10	279	0	27
1500	1549	3	11	686	0	46
1750	1112	0	9	466	0	13
2000	2139	4	11	744	0	34
2500	2335	2	12	579	0	16
3000	1997	2	6	399	0	28
3500	1464	6	2	142	0	15
4000	879	1	1	9	0	7
4500	487	0	0	8	0	7
5000	248	0	0	7	0	5
5500	31	0	0	1	0	0

Table 12. Nitrate 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	18.00	0.01	6.00	0.01	22.00
10	0.01	18.00	0.01	10.00	0.01	26.00
20	0.01	18.00	0.01	14.00	0.01	26.00
30	0.01	18.00	0.01	18.00	0.01	30.00
50	0.01	26.00	0.01	22.00	0.01	30.00
75	0.01	30.00	0.01	30.00	0.01	34.00
100	0.01	30.00	0.01	30.00	0.01	34.00
125	0.01	30.00	0.01	30.00	0.01	34.00
150	0.01	30.00	0.01	30.00	0.01	34.00
200	0.01	30.00	0.01	34.00	0.01	38.00
250	0.01	34.00	0.01	38.00	0.01	38.00
300	0.01	38.00	0.01	42.00	0.01	38.00
400	0.01	42.00	0.01	42.00	2.00	42.00
500	0.01	42.00	0.01	46.00	2.00	46.00
600	0.01	42.00	0.01	46.00	2.00	46.00
700	6.00	46.00	0.01	46.00	2.00	46.00
800	6.00	46.00	0.01	46.00	2.00	46.00
900	6.00	46.00	0.01	46.00	2.00	46.00
1000	6.00	46.00	0.01	46.00	2.00	46.00
1100	6.00	46.00	0.01	46.00	2.00	46.00
1200	6.00	48.00	0.01	42.00	6.00	42.00
1300	6.00	48.00	0.01	42.00	6.00	42.00
1400	6.00	48.00	2.00	42.00	6.00	42.00
1500	6.00	48.00	2.00	42.00	6.00	42.00
1750	6.00	48.00	10.00	42.00	6.00	42.00
2000	6.00	48.00	10.00	42.00	6.00	42.00
2500	6.00	48.00	10.00	42.00	6.00	42.00
3000	6.00	48.00	10.00	38.00	6.00	42.00
3500	10.00	48.00	10.00	38.00	6.00	42.00
4000	10.00	48.00	10.00	38.00	6.00	42.00
4500	10.00	46.00	10.00	38.00	6.00	42.00
5000	10.00	44.00	10.00	38.00	10.00	42.00
5500	14.00	42.00	10.00	38.00	14.00	34.00

Table 13. Nitrate 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	26.00	0.01	22.00	0.01	18.00
10	0.01	26.00	0.01	22.00	0.01	18.00
20	0.01	26.00	0.01	22.00	0.01	18.00
30	0.01	30.00	0.01	26.00	0.01	22.00
50	0.01	30.00	0.01	34.00	0.01	26.00
75	0.01	34.00	0.01	34.00	0.01	30.00
100	0.01	34.00	0.01	34.00	0.01	30.00
125	0.01	42.00	0.01	34.00	0.01	30.00
150	0.01	42.00	0.01	38.00	0.01	30.00
200	0.01	46.00	0.01	38.00	0.01	38.00
250	0.01	46.00	0.01	42.00	0.01	38.00
300	0.01	46.00	0.01	42.00	0.01	38.00
400	0.01	46.00	0.01	42.00	4.00	42.00
500	0.01	46.00	0.01	46.00	6.00	46.00
600	0.01	50.00	0.01	46.00	6.00	50.00
700	2.00	50.00	0.01	50.00	6.00	50.00
800	2.00	54.00	0.01	56.00	10.00	50.00
900	2.00	54.00	0.01	56.00	10.00	50.00
1000	2.00	54.00	0.01	56.00	10.00	50.00
1100	2.00	54.00	0.01	56.00	10.00	50.00
1200	2.00	54.00	0.01	56.00	10.00	54.00
1300	2.00	54.00	0.01	50.00	10.00	54.00
1400	2.00	54.00	2.00	50.00	10.00	54.00
1500	2.00	54.00	2.00	50.00	10.00	54.00
1750	2.00	54.00	2.00	50.00	10.00	54.00
2000	2.00	54.00	2.00	50.00	10.00	54.00
2500	2.00	54.00	2.00	50.00	10.00	54.00
3000	2.00	50.00	2.00	46.00	10.00	54.00
3500	2.00	46.00	2.00	46.00	10.00	54.00
4000	2.00	46.00	2.00	46.00	10.00	54.00
4500	2.00	42.00	2.00	46.00	10.00	42.00
5000	10.00	42.00	2.00	46.00	10.00	38.00
5500	14.00	42.00	2.00	46.00	14.00	38.00

Table 14. Nitrate 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	14.00	0.01	4.00	0.01	18.00
10	0.01	18.00	0.01	6.00	0.01	18.00
20	0.01	18.00	0.01	6.00	0.01	18.00
30	0.01	18.00	0.01	14.00	0.01	18.00
50	0.01	30.00	0.01	18.00	0.01	18.00
75	0.01	30.00	0.01	26.00	0.01	22.00
100	0.01	30.00	0.01	30.00	0.01	22.00
125	0.01	42.00	0.01	34.00	0.01	26.00
150	0.01	42.00	0.01	34.00	0.01	30.00
200	0.01	42.00	0.01	38.00	0.01	30.00
250	2.00	42.00	0.01	38.00	0.01	30.00
300	2.00	50.00	0.01	46.00	0.01	30.00
400	2.00	50.00	0.01	46.00	0.01	34.00
500	2.00	50.00	0.01	46.00	0.01	34.00
600	2.00	50.00	0.01	46.00	0.01	38.00
700	2.00	54.00	0.01	54.00	0.01	46.00
800	2.00	54.00	0.01	54.00	0.01	46.00
900	2.00	54.00	0.01	54.00	0.01	46.00
1000	2.00	54.00	0.01	54.00	0.01	46.00
1100	2.00	54.00	0.01	54.00	0.01	46.00
1200	2.00	54.00	0.01	54.00	0.01	46.00
1300	2.00	54.00	0.01	54.00	0.01	46.00
1400	2.00	54.00	0.01	54.00	0.01	46.00
1500	2.00	54.00	2.00	54.00	2.00	46.00
1750	2.00	54.00	2.00	54.00	2.00	46.00
2000	2.00	54.00	2.00	54.00	2.00	46.00
2500	4.00	54.00	2.00	54.00	2.00	46.00
3000	4.00	54.00	2.00	46.00	2.00	46.00
3500	4.00	54.00	2.00	46.00	2.00	46.00
4000	4.00	46.00	2.00	46.00	2.00	46.00
4500	4.00	46.00	2.00	46.00	2.00	46.00
5000	4.00	46.00	2.00	46.00	2.00	46.00
5500	10.00	46.00	2.00	46.00	10.00	46.00

Table 15. Nitrate ranges for the Southern and Arctic Oceans as a function of depth.

Depth	Southern Ocean		Arctic Ocean	
	Low	High	Low	High
0	0.01	46.00	0.01	18.00
10	0.01	46.00	0.01	18.00
20	0.01	46.00	0.01	18.00
30	0.01	46.00	0.01	18.00
50	0.01	46.00	0.01	18.00
75	0.01	46.00	0.01	18.00
100	0.01	46.00	0.01	22.00
125	0.01	46.00	0.01	22.00
150	0.01	46.00	0.01	22.00
200	0.01	46.00	0.01	26.00
250	0.01	46.00	0.01	26.00
300	0.01	46.00	0.01	26.00
400	4.00	46.00	0.01	28.00
500	6.00	46.00	0.01	28.00
600	6.00	46.00	0.01	32.00
700	6.00	46.00	0.01	32.00
800	14.00	46.00	0.01	42.00
900	14.00	46.00	0.01	42.00
1000	14.00	50.00	0.01	46.00
1100	14.00	50.00	0.01	46.00
1200	14.00	50.00	0.01	46.00
1300	14.00	50.00	0.01	50.00
1400	14.00	50.00	0.01	50.00
1500	14.00	50.00	0.01	50.00
1750	14.00	50.00	0.01	50.00
2000	14.00	50.00	0.01	54.00
2500	14.00	50.00	0.01	54.00
3000	14.00	50.00	0.01	54.00
3500	14.00	46.00	2.00	54.00
4000	14.00	46.00	2.00	46.00
4500	14.00	42.00	2.00	46.00
5000	14.00	42.00	2.00	46.00
5500	18.00	42.00	2.00	46.00

Table 16.Number of nitrate range outliers as a function of depth in the Atlantic Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Atlantic			Equatorial Atlantic			South Atlantic		
Depth	N	High	Low	N	High	Low	N	High	Low
0	3979	270	619	1771	84	448	1924	27	82
10	2793	255	430	1069	75	214	1261	11	40
20	2920	246	328	1269	70	242	1457	15	43
30	2269	272	291	1541	66	195	1373	6	52
50	3715	129	386	1887	52	208	1810	11	59
75	2740	55	246	1782	10	171	1502	6	40
100	3519	48	208	1575	10	90	1675	8	24
125	1044	13	67	891	2	27	626	1	17
150	2522	41	94	1443	9	17	1522	6	7
200	2965	47	78	1402	9	30	1857	5	
250	1295	10	58	1043	0	14	1219	2	0
300	2684	9	74	1212	0	12	1552	10	2
400	2440	10	58	1344	9	2	1983	2	21
500	2174	11	48	1109	3	2	1718	2	17
600	1835	5	42	851	1	0	1564	4	12
700	1368	8	50	635	6	0	1336	1	12
800	1668	1	90	641	2	0	1250	3	15
900	1167	3	37	420	6	0	939	2	6
1000	1641	8	86	496	5	1	952	4	18
1100	614	4	37	343	0	1	761	1	3
1200	1186	1	57	345	1	0	698	9	25
1300	584	2	36	244	1	0	604	1	9
1400	828	0	26	218	0	1	581	4	9
1500	1467	0	80	404	0	1	820	5	41
1750	1273	1	30	259	0	3	806	2	4
2000	1632	0	26	329	0	3	961	2	6
2500	1576	0	25	293	0	1	1122	2	9
3000	1117	0	16	276	0	3	1049	3	7
3500	852	0	20	240	0	1	943	3	5
4000	711	0	11	243	0	0	786	5	6
4500	591	0	10	189	0	0	579	1	8
5000	412	0	11	119	0	0	394	0	6
5500	129	0	3	43	0	0	148	10	0

Table 17. Number of nitrate range outliers as a function of depth in the Pacific Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Pacific			Equatorial Pacific			South Pacific		
Depth	N	High	Low	N	High	Low	N	High	Low
0	8243	150	2226	3246	22	787	1096	3	326
10	6473	127	1904	2199	20	577	414	4	104
20	5620	153	1552	2167	33	458	568	2	151
30	6556	104	1533	1834	33	341	385	3	78
50	9342	116	1880	3363	22	519	1086	1	289
75	8990	80	1224	3434	29	295	1037	4	239
100	8733	103	716	3831	16	127	1113	3	226
125	6152	11	257	3324	20	37	690	5	100
150	9358	36	171	5235	10	16	1216	7	129
200	9804	28	57	5380	19	5	1350	1	37
250	6111	15	26	4388	5	4	1002	1	2
300	8033	26	48	4439	10	3	1378	7	2
4oo	7175	33	24	3463	25	5	1151	4	8
500	6838	48	34	2677	12	4	941	3	2
600	5006	9	20	1635	21	4	732	1	2
700	3018	10	60	1076	4	5	741	2	1
800	3515	10	65	1139	4	3	591	6	4
900	2490	5	32	931	2	2	595	4	2
1000	3001	11	46	1050	3	1	620	4	0
1100	1699	5	21	625	0	1	453	1	1
1200	2023	11	33	582	0	2	388	1	0
1300	1166	1	25	395	2	2	345	0	0
1400	1140	6	18	291	0	3	215	1	1
1500	1865	6	27	540	0	5	418	0	0
1750	1643	5	12	367	1	1	391	0	0
2000	2430	9	16	655	0	2	599	0	0
2500	2291	3	10	675	1	0	700	0	0
3000	2178	7	10	569	3	0	703	0	0
3500	1911	2	7	433	1	0	645	0	0
4000	1610	4	2	375	0	0	506	0	0
4500	1397	4	1	251	0	0	339	2	0
5000	1057	5	30	171	0	0	201	2	0
5500	591	0	12	59	1	0	74	1	0

Table 18. Number of nitrate range outliers as a function of depth in the Indian Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Indian			Equatorial Indian			South Indian		
Depth	N	High	Low	N	High	Low	N	High	Low
0	228	5	23	861	4	341	1187	5	441
10	79	0	23	294	0	159	322	5	119
20	217	2	27	702	1	341	1018	7	387
30	103	1	21	413	0	157	391	5	153
50	234	1	21	890	0	228	1257	6	392
75	231	2	4	902	0	67	1064	3	250
100	258	2	0	998	3	6	1307	8	136
125	136	0	0	607	5	0	691	1	20
150	254	0	0	877	5	0	1250	0	28
200	258	3	0	908	3	0	1372	3	11
250	88	0	1	617	3	2	752	5	2
300	270	0	0	863	1	1	1348	6	1
400	274	2	0	787	4	0	1068	4	3
500	208	0	1	720	3	1	1130	9	4
600	192	1	0	531	4	0	696	8	0
700	95	2	0	204	3	0	650	2	1
800	182	1	0	417	0	0	536	3	1
900	93	1	1	126	3	0	538	1	0
1000	182	1	0	429	2	0	521	5	0
1100	25	0	0	120	1	0	464	4	0
1200	90	1	1	268	2	1	377	4	0
1300	38	0	0	151	1	0	454	2	0
1400	54	0	0	135	0	0	242	3	0
1500	89	1	0	248	0	3	563	1	7
1750	78	1	0	173	1	0	272	7	1
2000	130	0	0	331	2	0	587	5	4
2500	98	1	0	286	0	1	510	4	4
3000	90	1	0	213	0	0	388	1	3
3500	53	0	0	153	1	1	313	2	0
4000	28	0	0	165	1	1	286	1	0
4500	1	0	0	91	0	0	200	1	1
5000	0	0	0	22	0	0	98	0	2
5500	0	0	0	5	0	0	20	0	0

Table 19. Number of nitrate range outliers as a function of depth in the Southern and Arctic Oceans. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	Southern Ocean			Arctic Ocean		
	N	High	Low	N	High	Low
0	1490	0	8	4198	5	447
10	945	0	9	3401	8	335
20	933	1	2	3360	8	178
30	901	2	3	2593	17	84
50	1451	3	1	3057	7	30
75	1196	5	1	1889	5	9
100	1266	4	0	2285	1	3
125	543	1	0	436	0	2
150	1160	4	1	1383	2	3
200	1273	6	1	1538	1	1
250	692	3	0	857	0	0
300	1161	7	1	1135	0	2
400	1263	6	3	926	0	0
500	907	6	1	775	0	0
600	943	10	0	458	0	0
700	595	0	2	392	0	1
800	749	4	4	346	0	2
900	521	2	5	243	0	0
1000	744	3	17	285	0	0
1100	426	1	4	161	0	0
1200	529	2	3	238	0	0
1300	373	1	1	126	0	0
1400	412	0	2	136	0	0
1500	691	2	5	264	0	0
1750	849	1	6	245	0	0
2000	1198	0	13	356	0	0
2500	1466	1	2	303	0	0
3000	1246	0	4	233	0	0
3500	919	2	2	90	0	4
4000	527	0	1	6	0	3
4500	296	1	0	4	0	1
5000	185	0	0	5	0	1
5500	19	0	0	1	0	0

Table 20. Silicate 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	50.0	0.0	40.0	0.0	30.0
10	0.0	50.0	0.0	40.0	0.0	30.0
20	0.0	50.0	0.0	40.0	0.0	30.0
30	0.0	50.0	0.0	40.0	0.0	30.0
50	0.0	60.0	0.0	50.0	0.0	30.0
75	0.0	60.0	0.0	50.0	0.0	30.0
100	0.0	60.0	0.0	50.0	0.0	40.0
125	0.0	60.0	0.0	60.0	0.0	40.0
150	0.0	60.0	0.0	60.0	0.0	40.0
200	0.0	80.0	0.0	60.0	0.0	40.0
250	0.0	80.0	2.0	60.0	2.0	40.0
300	0.0	80.0	2.0	80.0	2.0	40.0
400	0.0	100.0	2.0	80.0	2.0	40.0
500	2.0	100.0	2.0	80.0	2.0	80.0
600	2.0	100.0	2.0	80.0	2.0	80.0
700	2.0	120.0	2.0	80.0	2.0	80.0
800	2.0	120.0	2.0	80.0	2.0	80.0
900	2.0	120.0	2.0	80.0	5.0	120.0
1000	2.0	120.0	2.0	80.0	5.0	120.0
1100	2.0	120.0	2.0	80.0	5.0	120.0
1200	2.0	120.0	2.0	80.0	5.0	120.0
1300	2.0	120.0	2.0	80.0	5.0	120.0
1400	2.0	120.0	2.0	80.0	5.0	120.0
1500	2.0	120.0	2.0	80.0	5.0	120.0
1750	2.0	120.0	2.0	80.0	5.0	120.0
2000	5.0	130.0	5.0	80.0	5.0	120.0
2500	10..0	150.0	5.0	80.0	5.0	120.0
3000	10..0	150.0	5.0	80.0	5.0	140.0
3500	15.0	150.0	5.0	100.0	5.0	140.0
4000	15.0	150.0	10..0	100.0	10.0	160.0
4500	15.0	150.0	15.0	120.0	10.0	160.0
5000	15.0	150.0	30.0	160.0	20.0	160.0
5500	15.0	150.0	30.0	160.0	20.0	160.0

Table 21. Silicate ranges for the Pacific Ocean as a function of depth.

Depth	North Pacific		Equatorial Pacific		South Pacific	
	Low	High	Low	High	Low	High
0	0.0	60.0	0.0	80.0	0.0	80.0
10	0.0	60.0	0.0	80.0	0.0	80.0
20	0.0	60.0	0.0	80.0	0.0	80.0
30	0.0	60.0	0.0	80.0	0.0	80.0
50	0.0	60.0	0.0	80.0	0.0	80.0
75	0.0	80.0	0.0	80.0	0.0	80.0
100	0.0	80.0	0.0	80.0	0.0	80.0
125	0.0	80.0	0.0	80.0	0.0	80.0
150	0.0	80.0	0.0	80.0	0.0	80.0
200	2.0	80.0	2.0	80.0	0.0	80.0
250	2.0	80.0	2.0	80.0	1.0	100.0
300	2.0	80.0	2.0	80.0	1.0	100.0
400	2.0	100.0	2.0	80.0	1.0	100.0
500	5.0	140.0	5.0	100.0	1.0	120.0
600	5.0	140.0	5.0	120.0	1.0	120.0
700	10.0	140.0	5.0	120.0	1.0	120.0
800	10.0	140.0	5.0	120.0	1.0	120.0
900	10.0	160.0	5.0	140.0	2.0	120.0
1000	15.0	180.0	5.0	140.0	2.0	120.0
1100	15.0	180.0	10.0	180.0	2.0	120.0
1200	15.0	180.0	10.0	180.0	2.0	120.0
1300	15.0	180.0	10.0	180.0	5.0	160.0
1400	15.0	180.0	15.0	180.0	5.0	160.0
1500	15.0	200.0	15.0	180.0	10.0	160.0
1750	20.0	200.0	15.0	180.0	10.0	160.0
2000	20.0	200.0	15.0	180.0	15.0	160.0
2500	20.0	200.0	15.0	180.0	15.0	180.0
3000	20.0	200.0	15.0	180.0	15.0	180.0
3500	20.0	200.0	15.0	180.0	15.0	180.0
4000	20.0	200.0	15.0	180.0	15.0	180.0
4500	30.0	200.0	15.0	180.0	15.0	180.0
5000	30.0	200.0	20.0	180.0	15.0	180.0
5500	30.0	200.0	20.0	180.0	15.0	180.0

Table 22. Silicate ranges for the Indian Ocean as a function of depth.

Depth	North Indian		Equatorial Indian		South Indian	
	Low	High	Low	High	Low	High
0	0.0	30.0	0.0	50.0	0.0	80.0
10	0.0	30.0	0.0	50.0	0.0	80.0
20	0.0	30.0	0.0	50.0	0.0	80.0
30	0.0	30.0	0.0	50.0	0.0	80.0
50	0.0	30.0	0.0	50.0	0.0	80.0
75	0.0	30.0	0.0	50.0	0.0	80.0
100	0.0	60.0	0.0	50.0	0.0	80.0
125	0.0	60.0	0.0	50.0	0.0	80.0
150	0.0	60.0	2.0	60.0	0.0	80.0
200	5.0	80.0	2.0	60.0	0.0	80.0
250	10.0	80.0	2.0	60.0	2.0	80.0
300	10.0	80.0	2.0	60.0	2.0	80.0
400	10.0	80.0	2.0	60.0	2.0	80.0
500	10.0	80.0	5.0	80.0	2.0	80.0
600	10.0	80.0	5.0	80.0	2.0	100.0
700	10.0	80.0	10.0	80.0	2.0	100.0
800	10.0	80.0	10.0	80.0	2.0	100.0
900	15.0	120.0	15.0	120.0	5.0	120.0
1000	15.0	120.0	15.0	120.0	5.0	120.0
1100	20.0	120.0	15.0	120.0	5.0	120.0
1200	20.0	120.0	15.0	120.0	5.0	120.0
1300	20.0	120.0	15.0	120.0	10.0	120.0
1400	25.0	160.0	20.0	140.0	10.0	120.0
1500	25.0	160.0	20.0	140.0	15.0	140.0
1750	30.0	160.0	20.0	140.0	15.0	140.0
2000	30.0	160.0	30.0	160.0	20.0	160.0
2500	30.0	160.0	30.0	160.0	20.0	160.0
3000	30.0	180.0	30.0	160.0	20.0	160.0
3500	30.0	180.0	30.0	160.0	20.0	160.0
4000	30.0	180.0	30.0	160.0	20.0	160.0
4500	30.0	180.0	30.0	160.0	20.0	160.0
5000	30.0	180.0	30.0	160.0	20.0	160.0
5500	30.0	180.0	30.0	160.0	20.0	160.0

Table 23. Silicate ranges for the Southern and Arctic Oceans as a function of depth.

Depth	Southern Ocean		Arctic Ocean	
	Low	High	Low	High
0	0.0	120.0	0.0	100.0
10	0.0	120.0	0.0	100.0
20	0.0	120.0	0.0	100.0
30	0.0	120.0	0.0	100.0
50	0.0	120.0	0.0	100.0
75	0.0	120.0	0.0	100.0
100	0.0	120.0	0.0	100.0
125	0.0	120.0	0.0	100.0
150	5.0	140.0	0.0	100.0
200	5.0	140.0	0.0	100.0
250	5.0	140.0	0.0	100.0
300	5.0	140.0	2.0	120.0
400	5.0	140.0	2.0	120.0
500	5.0	160.0	2.0	120.0
600	10.0	160.0	2.0	120.0
700	10.0	160.0	2.0	120.0
800	15.0	160.0	5.0	80.0
900	25.0	160.0	5.0	80.0
1000	25.0	160.0	5.0	80.0
1100	25.0	160.0	5.0	80.0
1200	25.0	160.0	5.0	80.0
1300	25.0	160.0	5.0	80.0
1400	25.0	160.0	5.0	80.0
1500	30.0	160.0	5.0	80.0
1750	30.0	160.0	5.0	80.0
2000	30.0	160.0	5.0	80.0
2500	35.0	160.0	5.0	80.0
3000	35.0	160.0	5.0	80.0
3500	35.0	160.0	5.0	80.0
4000	35.0	160.0	5.0	80.0
4500	35.0	160.0	5.0	80.0
5000	35.0	160.0	5.0	80.0
5500	35.0	160.0	5.0	80.0

Table 24. Number of silicate range outliers as a function of depth in the Atlantic Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Atlantic			Equatorial Atlantic			South Atlantic		
Depth	N	High	Low	N	High	Low	N	High	Low
0	7347	99	0	2509	11	0	2288	57	0
10	4956	36	0	1904	6	0	1436	40	0
20	4676	22	0	1851	5	0	1650	13	0
30	4798	37	0	2300	8	0	1536	42	0
50	7300	83	0	2691	4	0	2121	62	0
75	5112	35	0	2584	5	0	1773	12	0
100	7026	132	0	2469	7	0	1913	40	0
125	2124	27	0	1308	2	0	732	7	0
150	5017	140	0	2139	1	0	1824	34	0
200	6354	111	0	2370	4	0	2177	56	0
250	3222	67	0	1526	7	16	1393	25	78
300	5885	141	0	2128	2	10	1959	92	52
400	5275	117	0	2202	2	11	2386	125	36
500	5221	135	405	2032	6	7	2014	30	16
600	4110	169	214	1378	1	6	1845	41	15
700	2821	102	61	879	1	1	1483	41	4
800	3806	122	129	1081	11	4	1536	61	12
900	2591	129	32	668	4	1	1065	26	6
1000	3505	114	104	983	7	6	1211	66	10
1100	1785	73	19	549	3	4	835	18	1
1200	2372	78	45	615	2	1	830	43	10
1300	1370	47	12	359	2	1	654	19	1
1400	1508	42	13	336	0	1	710	16	2
1500	2951	86	46	698	1	3	1020	54	7
1750	2539	95	16	430	1	4	933	13	1
2000	3291	150	59	589	0	2	1261	20	5
2500	2967	131	149	469	1	3	1449	31	4
3000	2289	150	97	452	3	0	1346	13	3
3500	1734	132	101	404	0	0	1181	20	1
4000	1536	124	34	396	1	0	997	11	1
4500	1344	117	15	290	2	0	727	13	1
5000	974	69	10	153	0	5	462	6	0
5500	286	1	3	49	1	0	163	0	0

Table 25. Number of silicate range outliers as a function of depth in the Pacific Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Pacific			Equatorial Pacific			South Pacific		
Depth	N	High	Low	N	high	Low	N	High	Low
0	14525	117	0	3869	70	0	4188	229	0
10	11090	104	0	2452	59	0	2545	195	0
20	9444	116	0	2672	63	0	2931	190	0
30	11277	111	0	2278	79	0	2703	188	0
50	15613	150	0	3747	79	0	3349	178	1
75	13111	58	0	3618	105	0	2889	156	0
100	13866	79	0	3909	112	0	3013	135	1
125	8438	43	0	2852	74	0	1664	55	0
150	12862	193	0	4559	149	0	2852	117	0
200	13986	402	550	4215	149	198	3351	107	0
250	8382	264	180	3267	133	31	2317	52	125
300	11453	622	170	3621	153	44	3076	76	198
400	10634	398	69	2787	55	30	2254	47	112
500	10644	105	129	2406	53	90	1818	12	99
600	7546	107	53	1615	21	31	1428	9	64
700	5060	137	38	1021	4	15	1231	10	72
800	5584	365	50	1146	39	26	1216	5	38
900	3591	71	22	862	8	9	852	7	64
1000	4770	95	94	1137	30	19	1186	11	88
1100	2765	51	37	519	10	9	593	4	45
1200	3403	95	57	567	19	19	727	1	54
1300	1631	49	17	267	1	12	305	0	48
1400	1889	53	16	270	0	9	297	0	44
1500	3449	72	22	579	12	11	547	0	84
1750	2738	47	25	369	3	6	480	0	46
2000	3666	75	65	693	19	12	719	2	83
2500	3202	70	24	662	15	20	778	0	55
3000	2950	27	29	549	2	20	785	0	44
3500	2425	19	25	411	0	13	715	0	37
4000	2090	16	39	339	2	5	537	0	15
4500	1555	9	1	222	1	3	359	0	9
5000	1252	1	1	166	0	0	210	0	3
5500	688	2	0	54	0	0	74	0	1

Table 26. Number of silicate range outliers as a function of depth in the Indian Ocean. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	North Indian			Equatorial Indian			South Indian		
Depth	N	High	Low	N	High	Low	N	High	Low
0	393	3	0	1334	6	0	2213	78	0
10	103	0	0	690	0	0	1547	57	0
20	290	0	0	897	7	0	1696	53	0
30	98	0	0	712	7	0	1456	52	0
50	379	2	0	1166	4	0	2049	53	0
75	294	5	0	997	1	0	1582	44	0
100	362	3	0	1110	25	0	1730	45	0
125	145	1	0	562	4	0	629	15	0
150	309	6	0	1013	26	5	1539	35	0
200	352	5	1	1131	33	7	1606	33	0
250	105	7	0	679	27	3	773	16	55
300	258	5	0	849	5	4	1333	31	99
400	308	4	0	941	10	1	1294	38	51
500	297	9	0	982	24	4	1097	33	31
600	238	3	0	595	2	1	876	17	21
700	145	8	0	379	10	5	513	15	13
800	244	14	0	696	47	2	844	23	10
900	122	4	0	306	5	6	450	13	27
1000	261	3	0	731	25	3	820	29	26
1100	74	3	0	264	13	5	334	13	16
1200	127	4	0	390	27	3	472	24	15
1300	56	1	0	271	12	4	299	13	11
1400	64	0	0	224	5	4	325	15	9
1500	157	5	0	472	24	3	606	33	19
1750	123	1	0	387	19	0	476	14	6
2000	165	4	0	559	6	6	849	13	16
2500	123	3	0	499	1	5	674	13	4
3000	113	1	0	413	3	0	541	15	4
3500	52	1	0	272	3	0	368	10	2
4000	36	0	0	263	3	0	318	10	2
4500	2	0	0	149	0	0	205	5	0
5000	1	0	0	39	0	0	100	4	1
5500	0	0	0	3	0	0	25	0	0

Table 27. Number of silicate range outliers as a function of depth in the Southern and Arctic Oceans. (N= number of observations, High= outliers exceeding high range values, Low= outliers below the low range values)

	Southern Ocean			Arctic Ocean		
Depth	N	High	Low	N	High	Low
0	3301	14	0	6919	279	0
10	2400	12	0	4887	418	0
20	2390	11	0	5758	220	0
30	2385	2	0	3577	170	0
50	3738	16	0	5504	82	0
75	2842	20	0	2627	57	0
100	2924	17	0	4692	51	0
125	925	6	0	618	7	0
150	2701	11	89	2285	36	0
200	2918	16	73	3801	32	0
250	1393	11	29	1642	13	0
300	2639	21	32	3003	24	76
400	2660	18	19	2048	28	41
500	1840	14	13	2520	24	41
600	1877	1	22	1342	22	36
700	1048	5	7	568	15	18
800	1676	9	11	1633	19	172
900	826	4	22	386	11	29
1000	1616	16	20	1577	15	132
1100	696	3	8	223	4	14
1200	889	8	12	387	8	20
1300	560	1	5	160	1	8
1400	667	6	0	185	0	14
1500	1434	10	13	482	2	15
1750	1188	9	13	328	2	7
2000	2108	17	10	520	2	10
2500	2367	18	18	408	0	10
3000	2022	17	19	326	0	6
3500	1514	9	10	126	2	5
4000	936	8	7	6	0	3
4500	521	8	0	4	0	2
5000	264	5	0	3	0	0
5500	31	0	0	2	0	0

Table 28. 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 29. Number of observations interpolated from observed levels to standard levels using the different interpolation schemes (numbers in parenthesis are percent of standard levels filled using each method).

SD file	Phosphate	Nitrate	Silicate
Direct substitution	609013 (38.9%)	207865 (34.6%)	313825 (35.3%)
Reineger Ross	639378 (40.8%)	267368 (44.5%)	370043 (41.7%)
Two above one below interpolation	99687 (6.4%)	38059 (6.3%)	61934 (7.0%)
One above two below interpolation	55670 (3.5%)	26066 (4.3%)	38708 (4.3%)
Linear Interpolation	162765 (10.4%)	61227 (10.2%)	103651 (11.7%)
Total standard levels	1566513	600585	888161

SD2 file	Phosphate	Nitrate	Silicate
Direct substitution	120398 (63.9%)	38867 (61.5%)	78008 (55.2%)
Reineger Ross	48693 (25.8%)	12439 (19.7%)	29410 (20.8%)
Two above one below interpolation	6525 (3.5%)	4034 (6.4%)	10433 (7.4%)
One above two below interpolation	5016 (2.7%)	2774 (4.4%)	9699 (6.8%)
Linear Interpolation	7697 (4.1%)	5045 (8.0%)	13891 (9.8%)
Total standard levels	188329	63159	141441

Table 30. Cruises flagged due to nitrate errors in the SD file (F.S.U. refers to the Former Soviet Union)

NODC Cruise	Country	Date	Location	Profiles
88	South Africa	March 1977	South Pacific	21
1182	U.S.	Jan-Mar 1966	North Pacific	80
7064	F.S.U.	May-Jun 1982	Equatorial Indian	37
7065	F.S.U.	Jun-Jul 1982	Equatorial Indian	73
8638	U.S.	Nov-Dec 1983	South Atlantic	84

Table 31. Cruises flagged due to silicate errors in the SD file (F.S.U. refers to the Former Soviet Union)

NODC Cruise	Country	Date	Location	Profiles
44	F.S.U.	Jul-Aug 1960	North Pacific	233
251	U.S.	Feb-Mar 1964	North Atlantic	171
380	F.S.U.	Jun-Sep 1972	North Atlantic	362
392	Canada	Aug-Oct 1965	North Atlantic	147
8638	U.S.	Nov-Dec 1983	South Atlantic	84

Table 32. Number of profiles containing flagged observations for each step of the quality control of phosphate data.

QC PROCEDURE	WINTER		SPRING		SUMMER		FALL		TOTAL	
	SD	SD2	SD	SD2	SD	SD2	SD	SD2	SD	SD2
RANGE CHECK	2332	550	2309	417	2874	502	1739	444	9254	1913
STATISTICAL CHECK	1130	191	1348	145	1750	134	935	131	5163	601
OBJECTIVE ANALYSIS	77	144	121	57	114	142	81	33	393	376

Table 33. Number of profiles containing flagged observations for each step of the quality control of nitrate data.

QC PROCEDURE	WINTER		SPRING		SUMMER		FALL		TOTAL	
	SD	SD2	SD	SD2	SD	SD2	SD	SD2	SD	SD2
RANGE CHECK	2118	137	2883	153	2853	121	1498	124	9352	535
STATISTICAL CHECK	565	16	545	19	573	19	354	19	2037	68
OBJECTIVE ANALYSIS	49	16	26	2	34	0	46	8	155	26

Table 34. Number of profiles containing flagged observations for each step of the quality control of silicate data.

QC PROCEDURE	WINTER		SPRING		SUMMER		FALL		TOTAL	
	SD	SD2	SD	SD2	SD	SD2	SD	SD2	SD	SD2
RANGE CHECK	2826	398	3013	317	3608	410	2017	317	11464	1502
STATISTICAL CHECK	670	1	772	0	1056	0	463	3	3193	272
OBJECTIVE ANALYSIS	451	0	76	0	114	0	161	0	451	0

Table 35. Number of profiles (N) containing observations flagged during the range check, and the percentage of low and high outliers (% Low and % High) for each basin.

Basins	Phosphate			Nitrate			Silicate		
	Total N	% low	% high	Total N	% low	% high	Total N	% low	% high
N. Atlantic	5688	0.7	1.7	5127	6.4	2.5	4677	1.3	2.6
Eq.Atlantic	1367	0.3	1.8	2108	6.5	1.6	197	0.2	0.3
S. Atlantic	591	0.5	0.6	780	1.6	0.5	1413	0.6	2.6
N. Pacific	4288	0.5	0.6	13242	8.2	0.8	5836	0.8	1.8
Eq. Pacific	2165	1.4	0.7	3527	5.3	0.5	2151	1.1	2.6
S. Pacific	4161	3.0	3.5	1777	7.5	0.3	3217	2.7	3.4
N. Indian	109	0.2	1.2	152	2.8	0.7	106	0.0	1.8
Eq. Indian	606	0.7	1.1	1361	9.0	0.4	455	0.4	1.9
S. Indian	1543	1.1	1.8	2092	9.0	0.6	1300	1.5	2.9
Antarctic	454	0.5	0.2	180	0.4	0.3	796	0.8	0.6
Arctic	1041	0.5	0.6	1160	3.5	0.2	2203	1.1	2.6
Total	22013	9.4	13.8	31506	60.2	8.4	22351	10.5	23.1

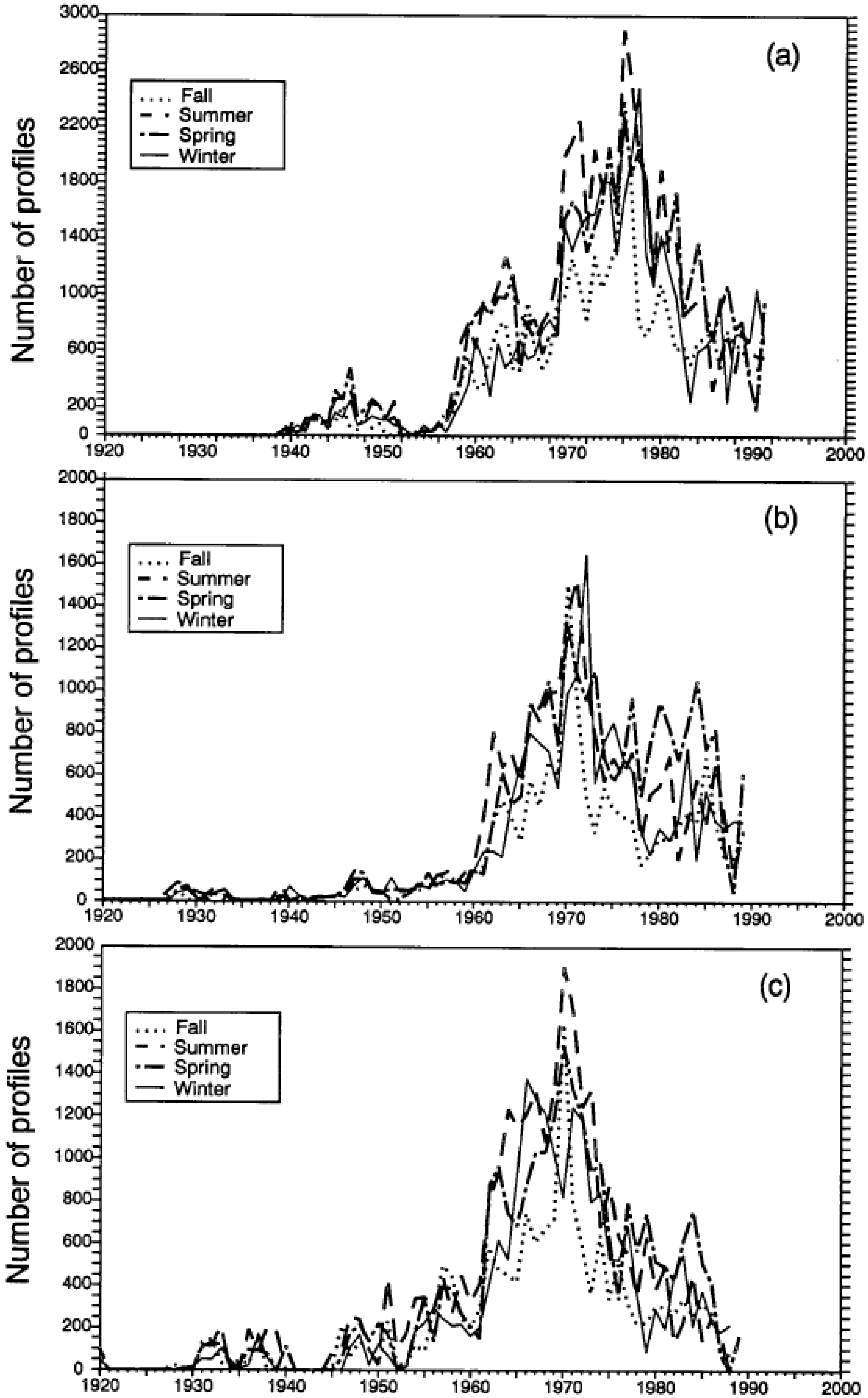


Fig 1 Seasonal distribution of (a) phosphate, (b) nitrate and (c) silicate profiles as a function of year for each season

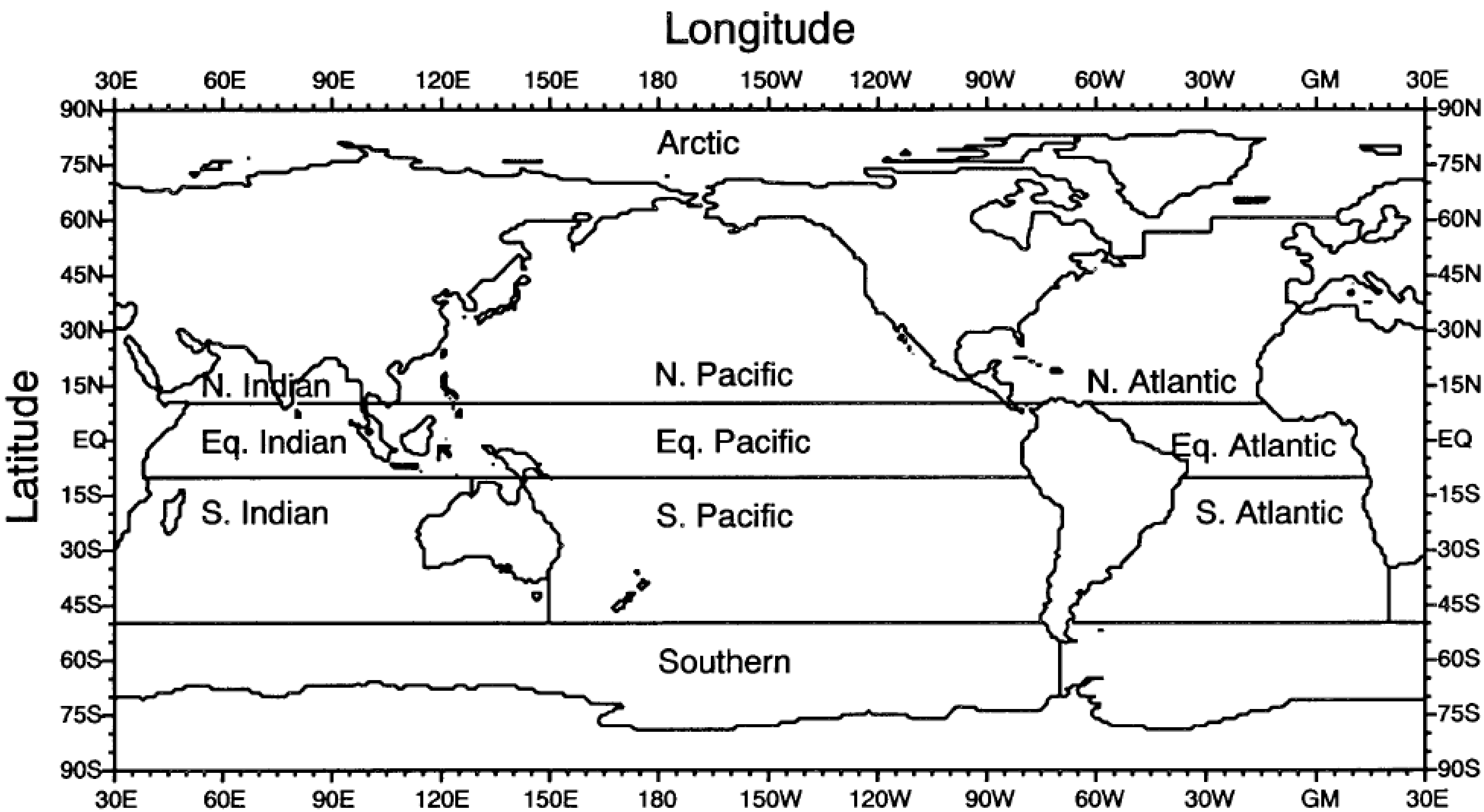


Fig 2. Division of world ocean into individual basins

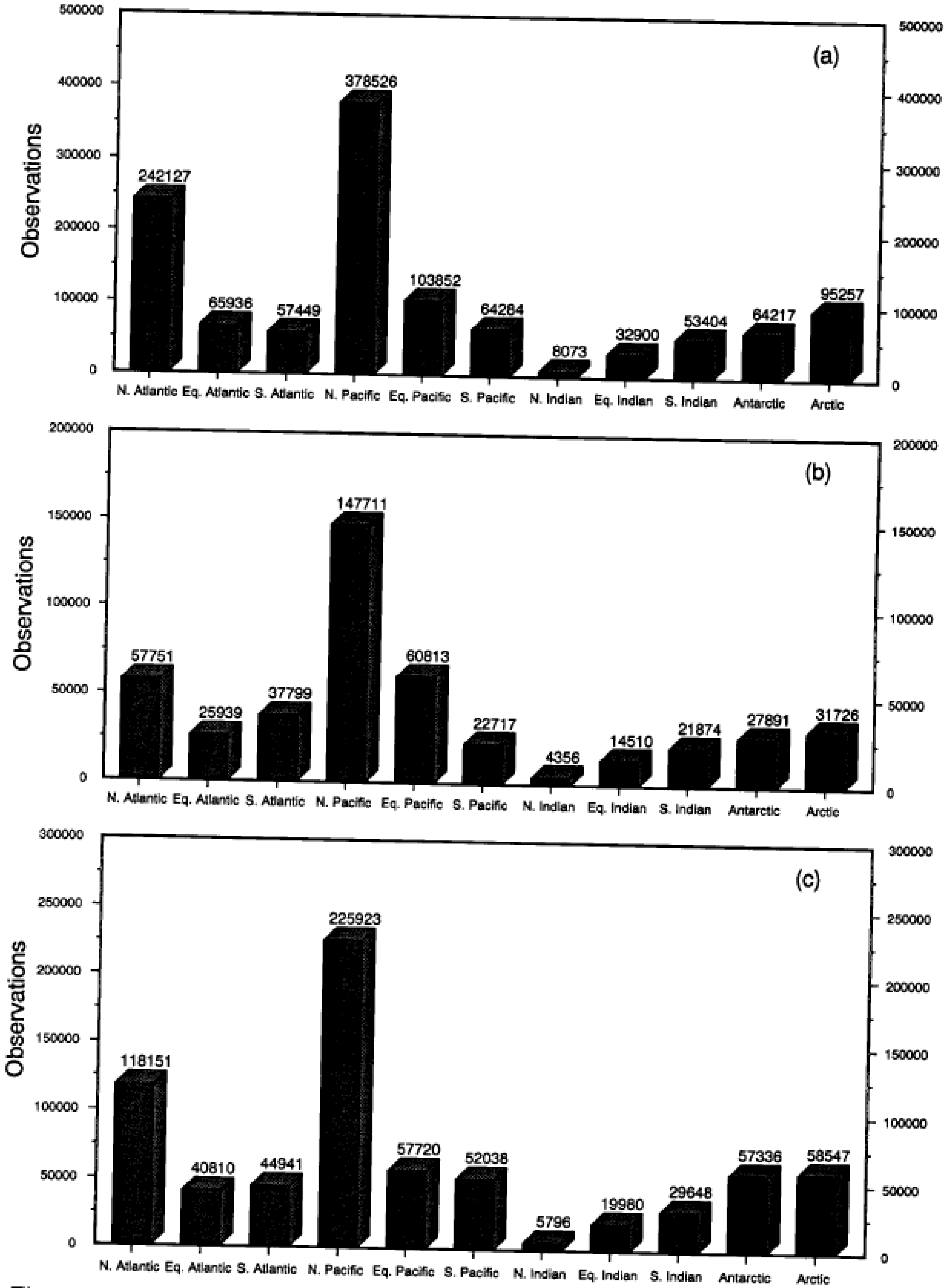


Fig 3. Total number of (a) phosphate, (b) nitrate and (c) silicate observations for each basin used in this study

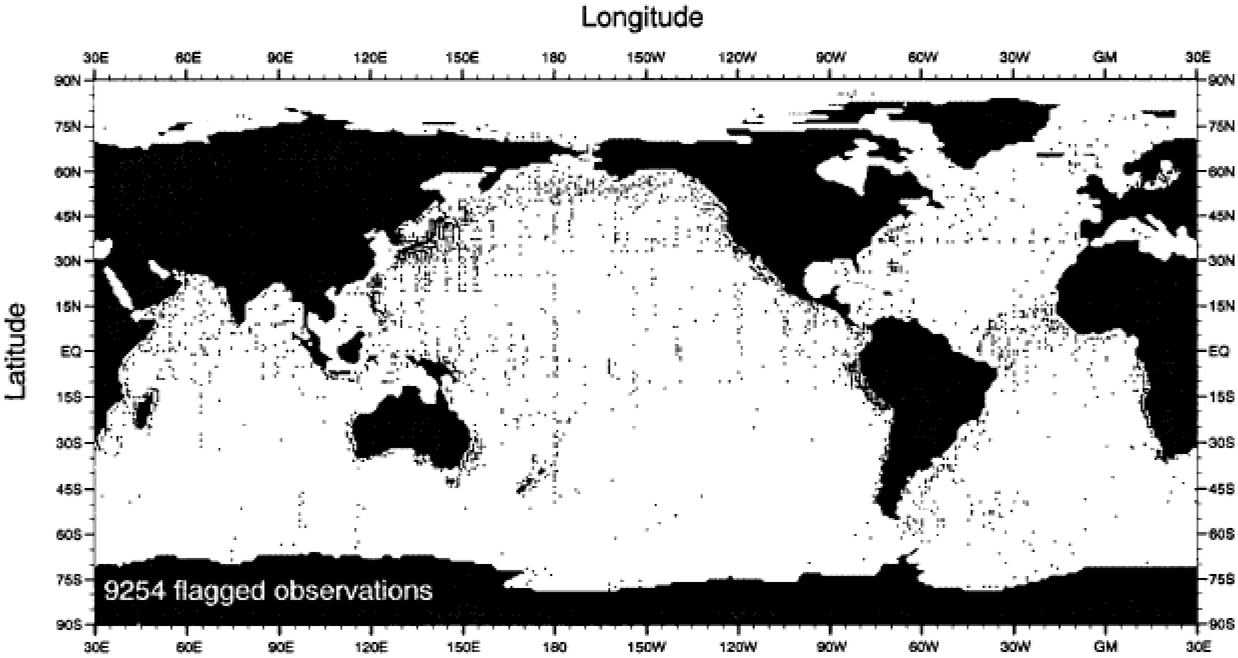


Fig. 4a Location of phosphate range check flags in the SD file

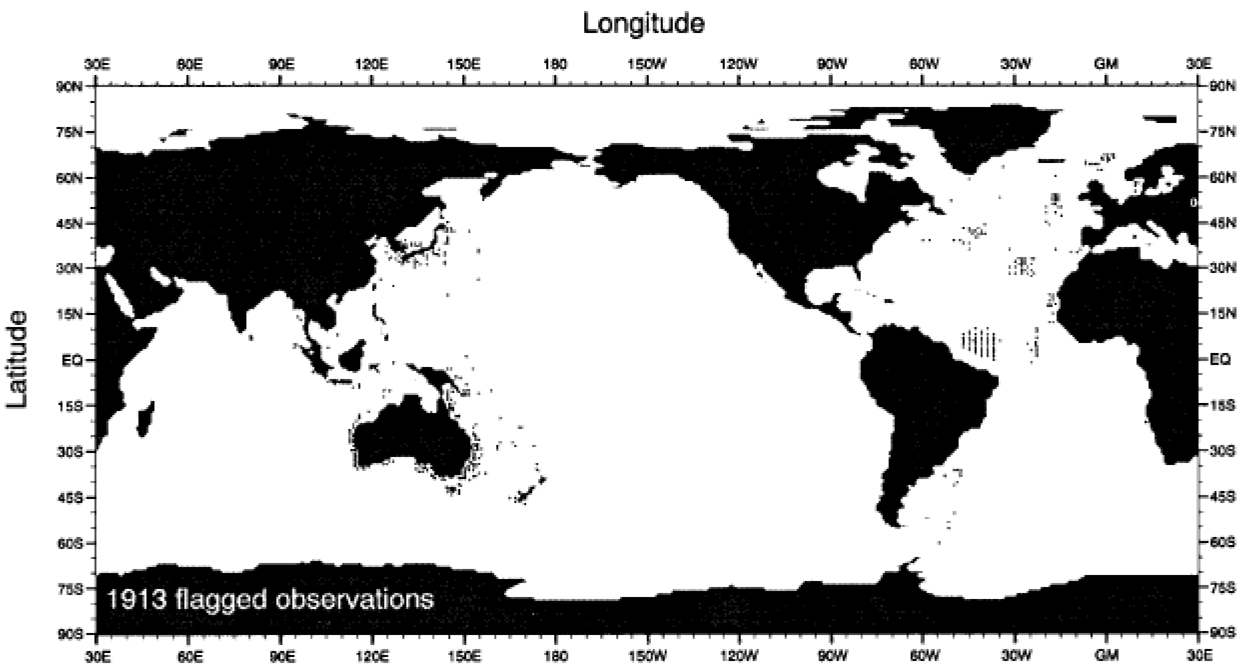


Fig. 4b Location of phosphate range check flags in the SD2 file

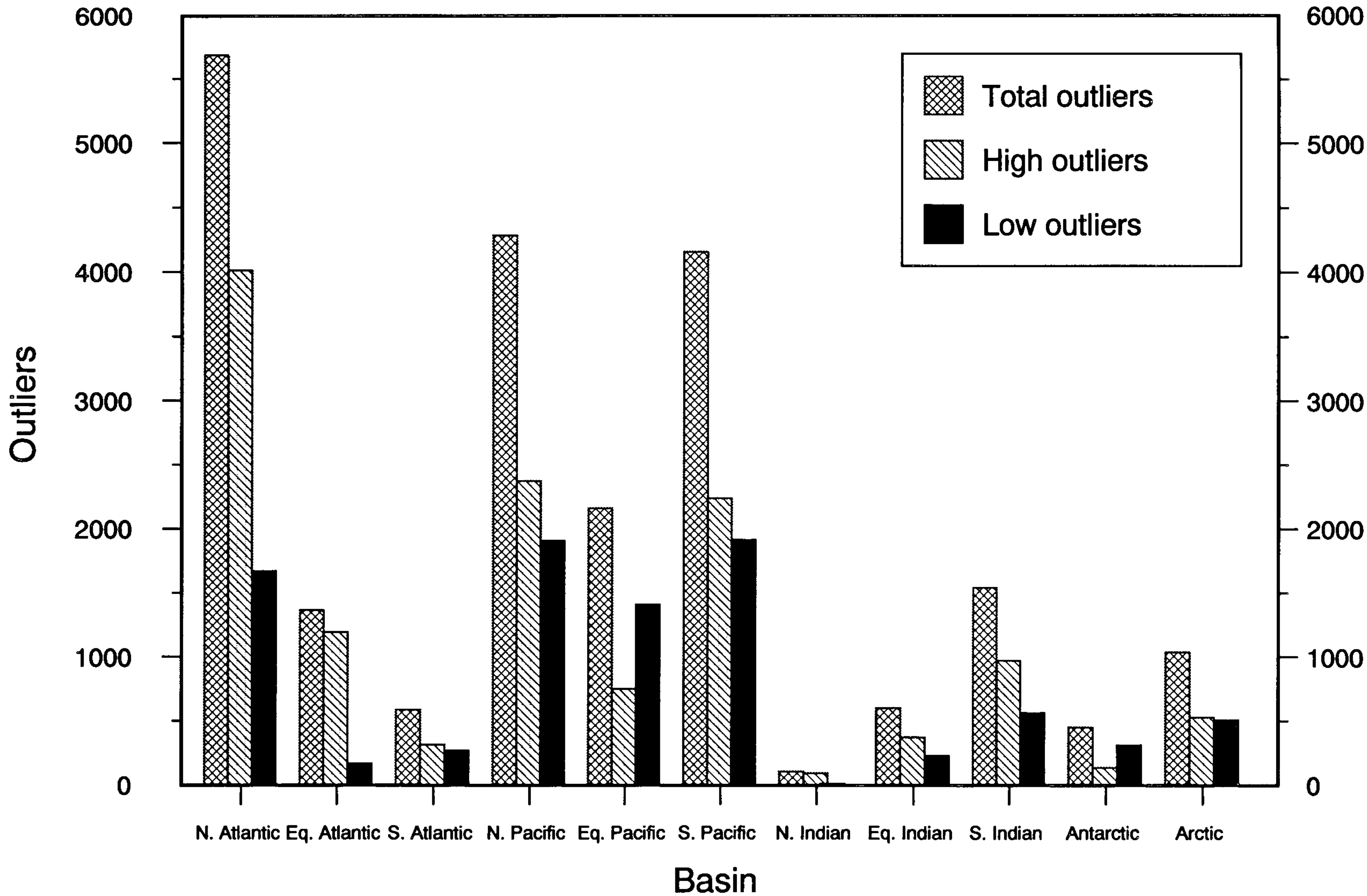


Fig 5. Total number of phosphate outliers from the range check, and the number of values above (high outliers) and below (low outliers) the ranges set for each basin used in this study

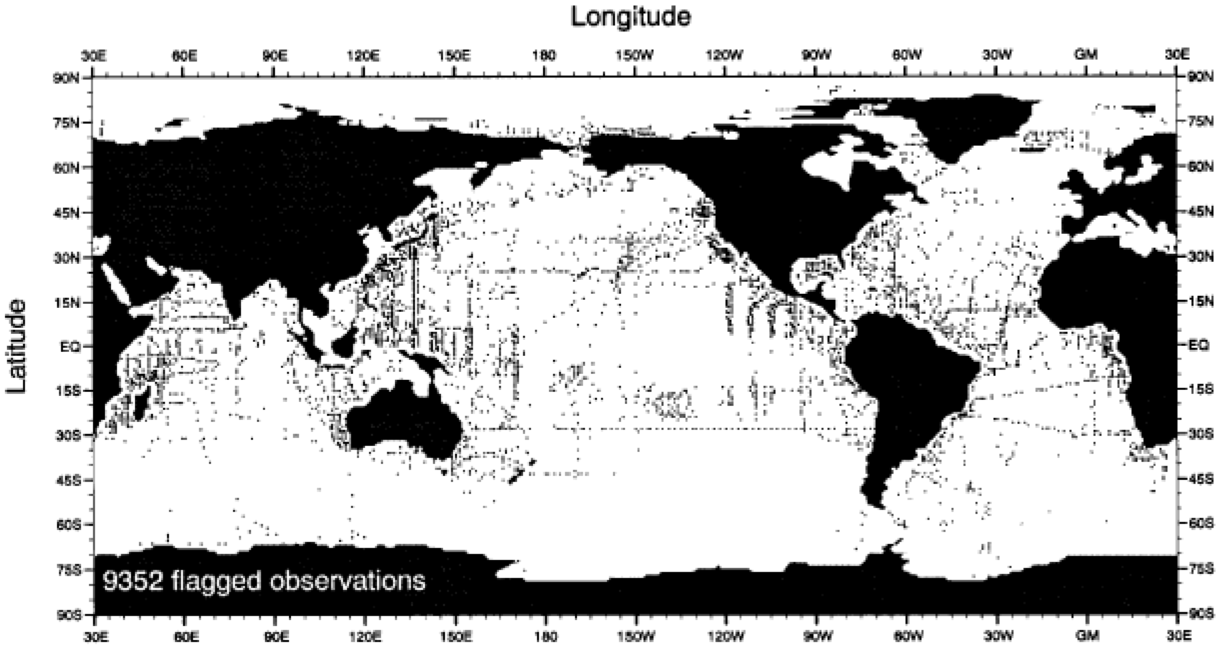


Fig. 6a Location of nitrate range check flags in the SD file

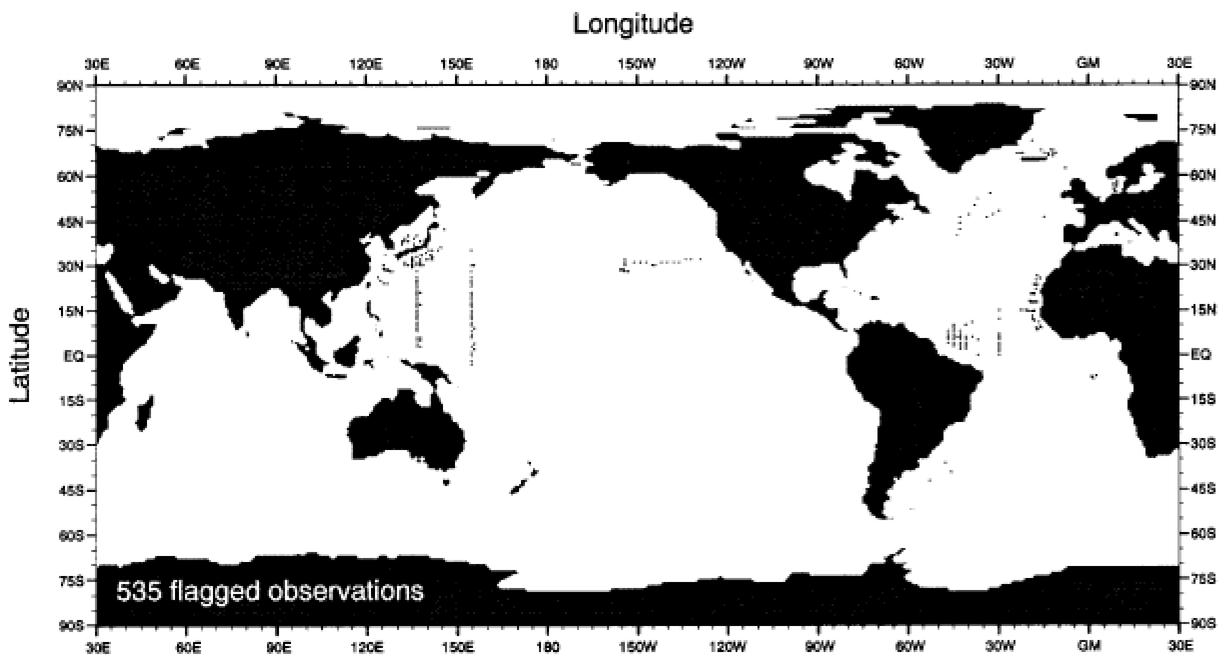


Fig. 6b Location of nitrate range check flags in the SD2 file

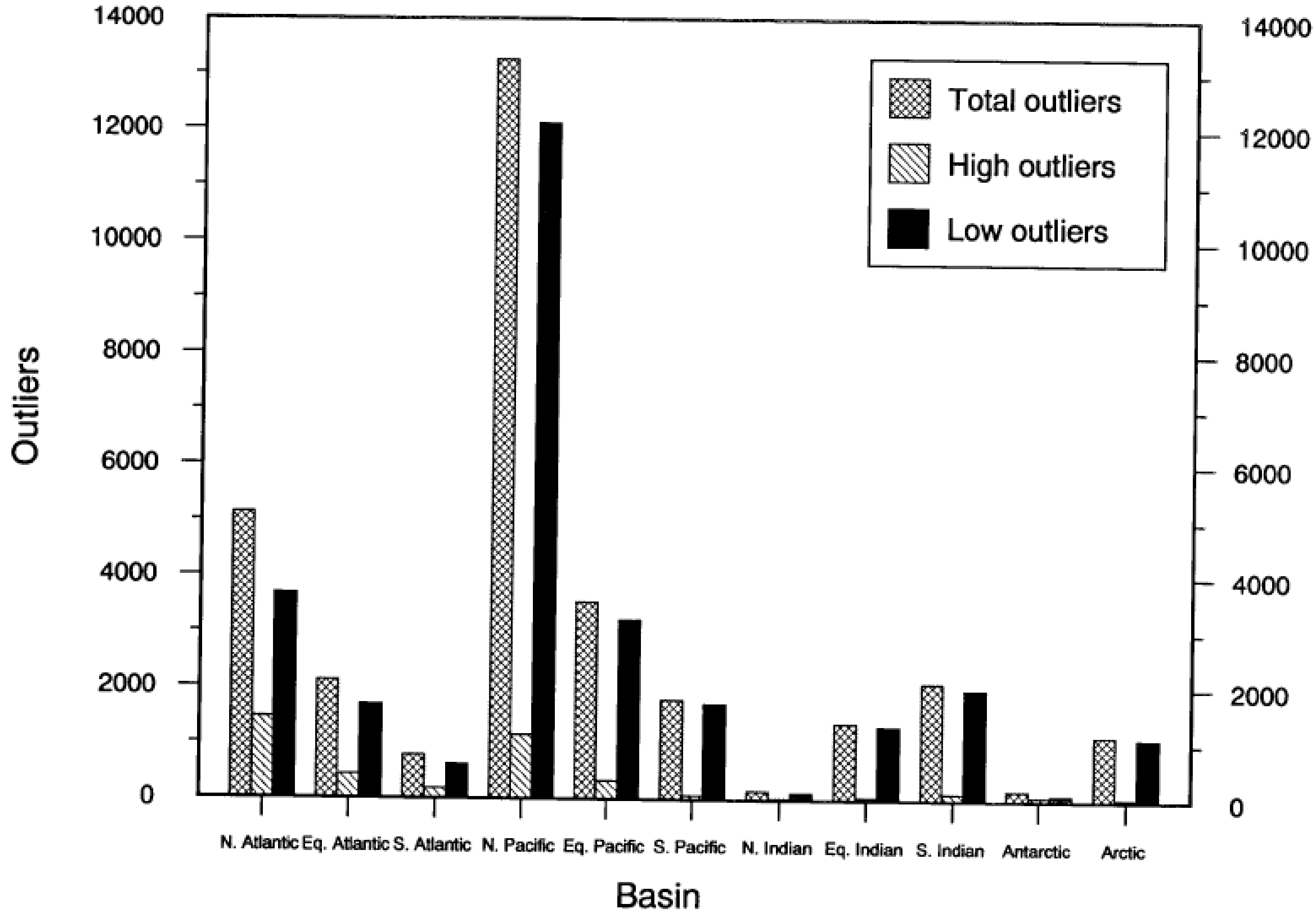


Fig 7. Total number of nitrate outliers from the range check, and the number of values above (high outliers) and below (low outliers) the ranges set for each basin used in this study

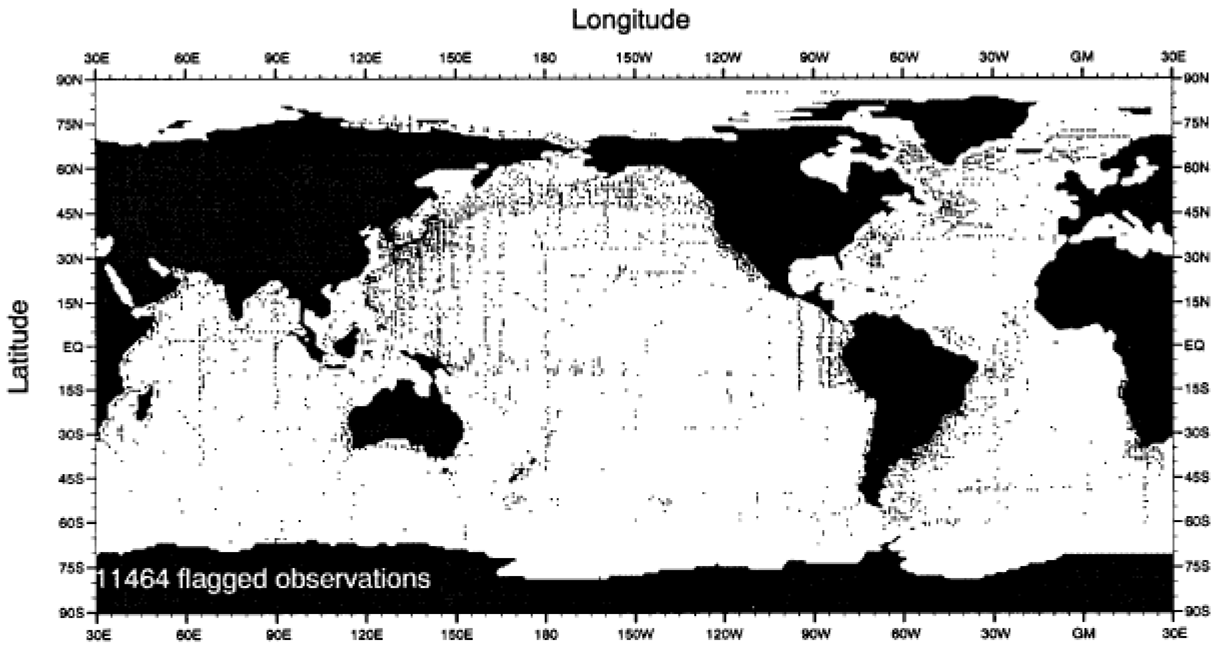


Fig. 8a Location of silicate range check flags in the SD file

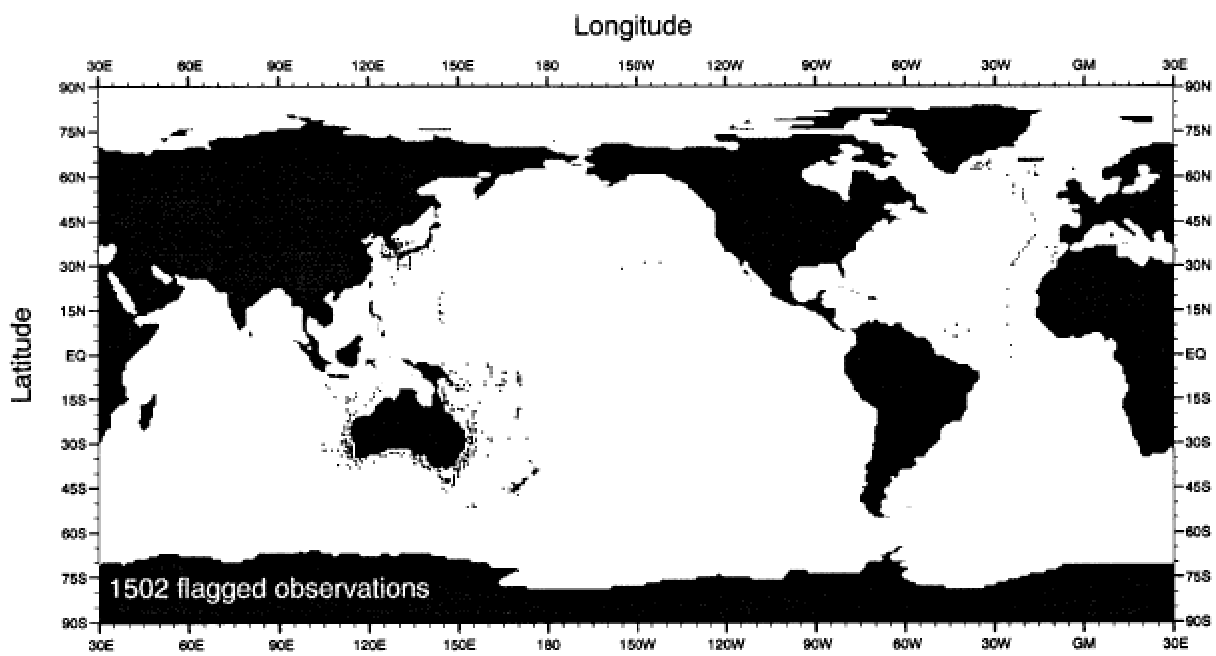


Fig. 8b Location of silicate range check flags in the SD2 file

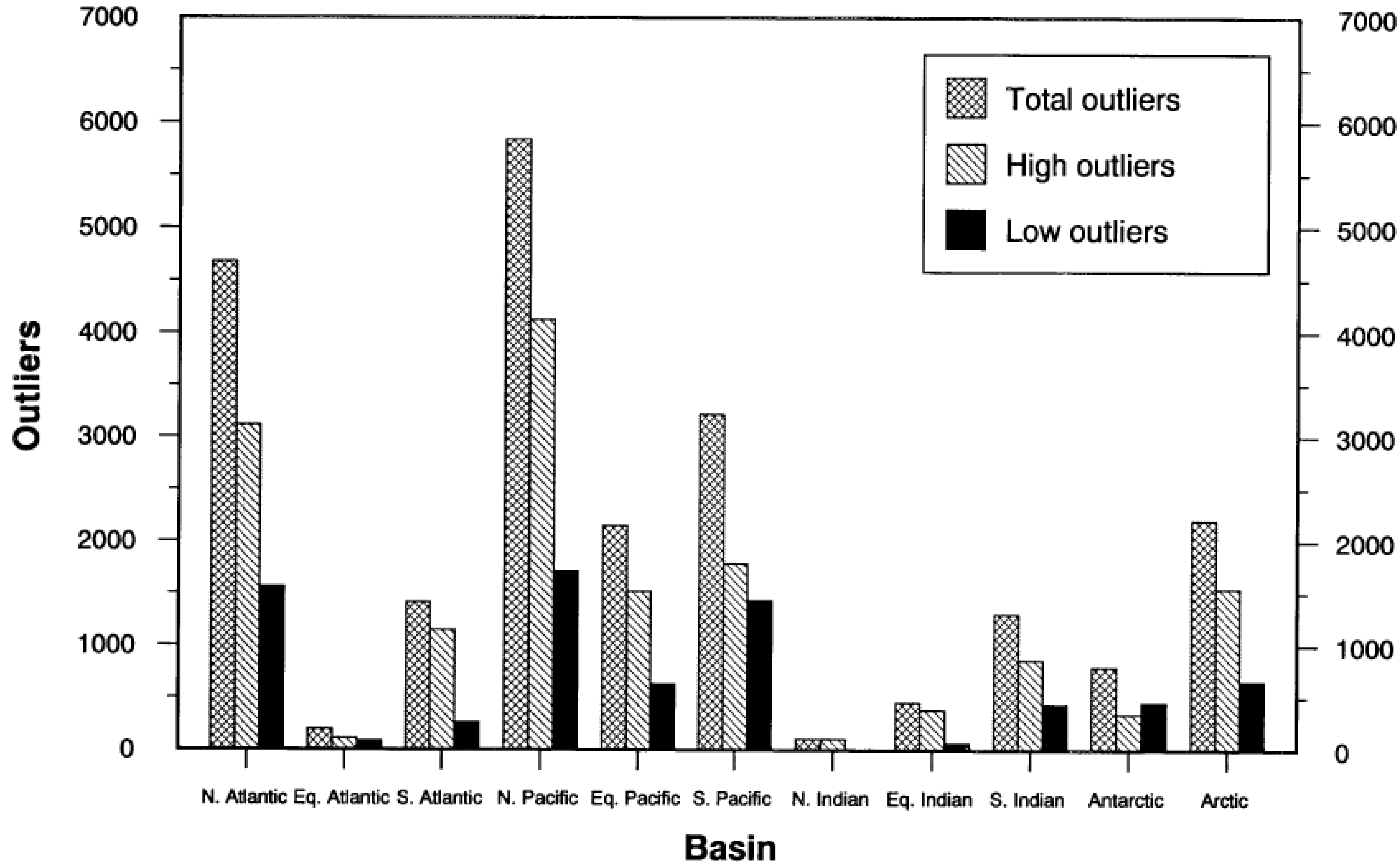


Fig 9. Total number of silicate outliers from the range check, and the number of values above (high outliers) and below (low outliers) the ranges set for each basin used in this study

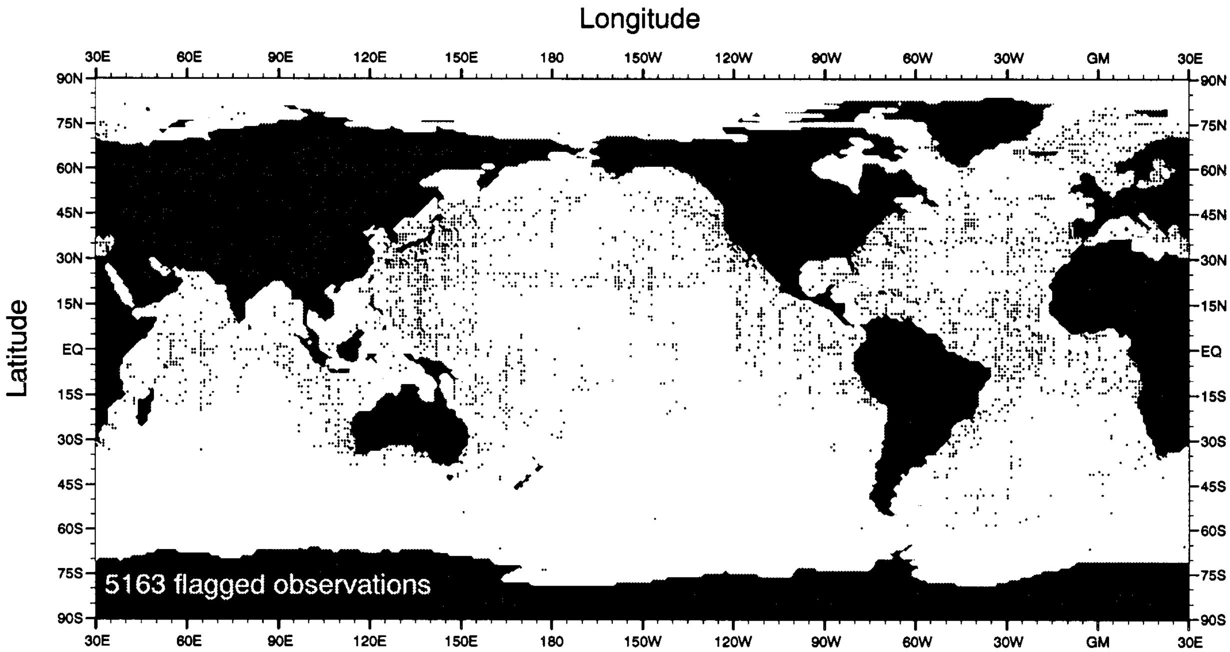


Fig. 10a Location of phosphate statistical check flags in the SD file

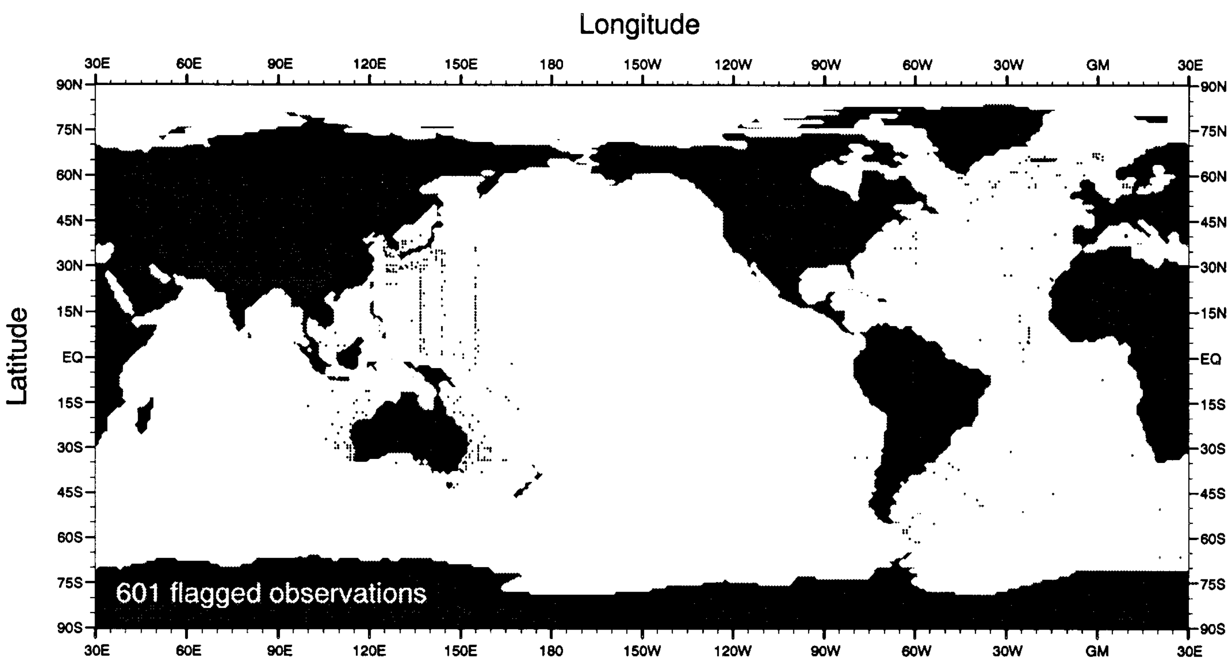


Fig. 10b Location of phosphate statistical check flags in the SD2 file

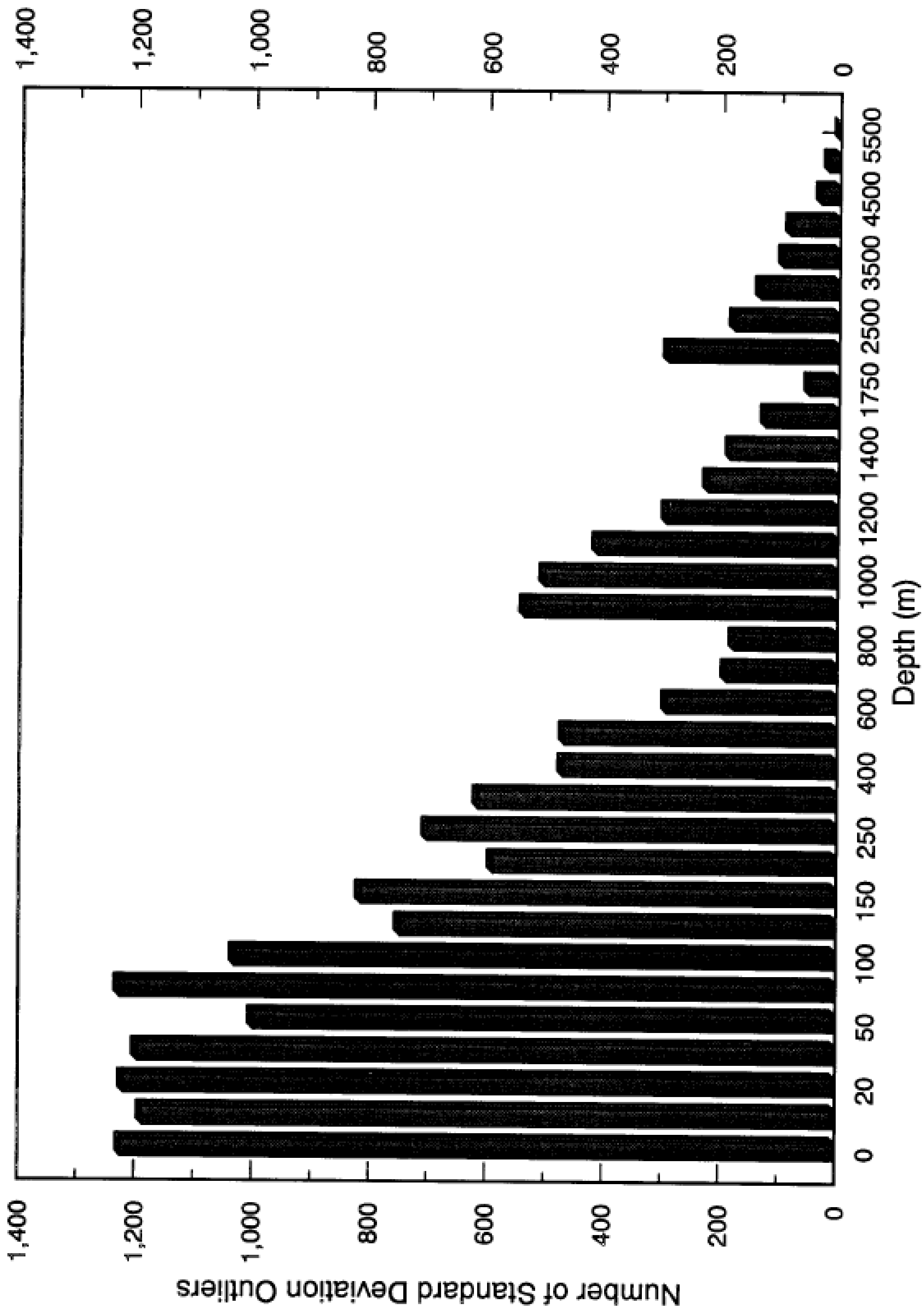


Fig. 11 Phosphate outliers with depth from the standard deviation check

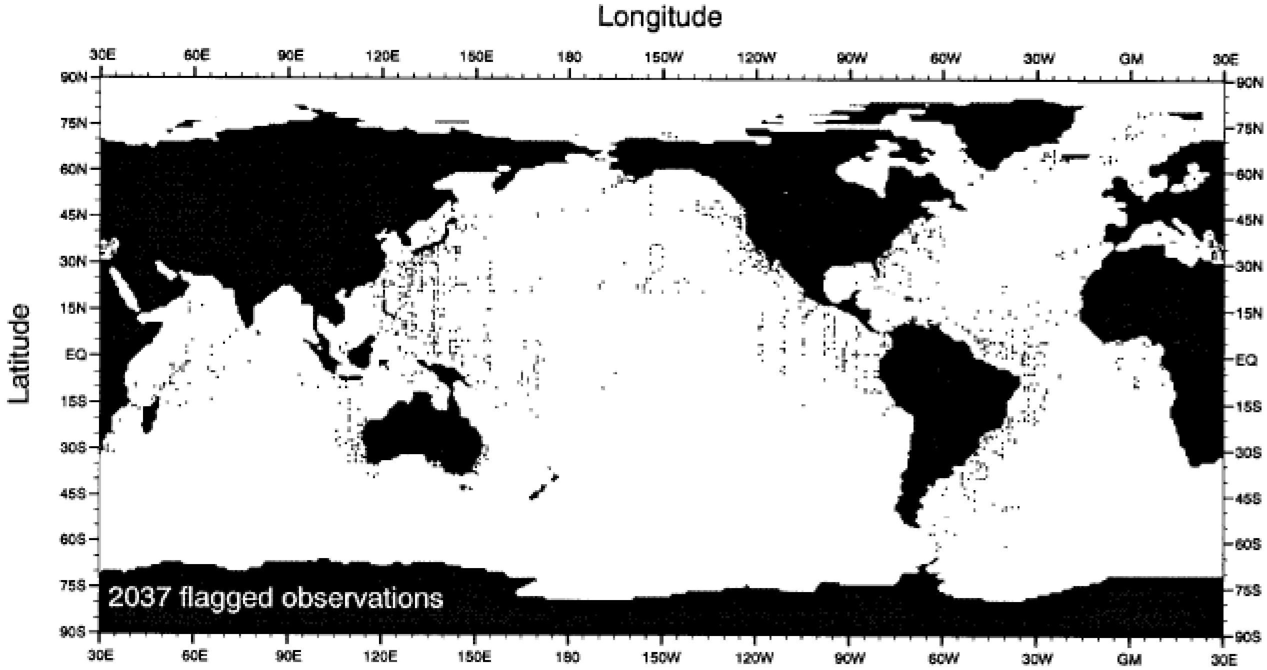


Fig. 12a Location of nitrate statistical check flags in the SD file

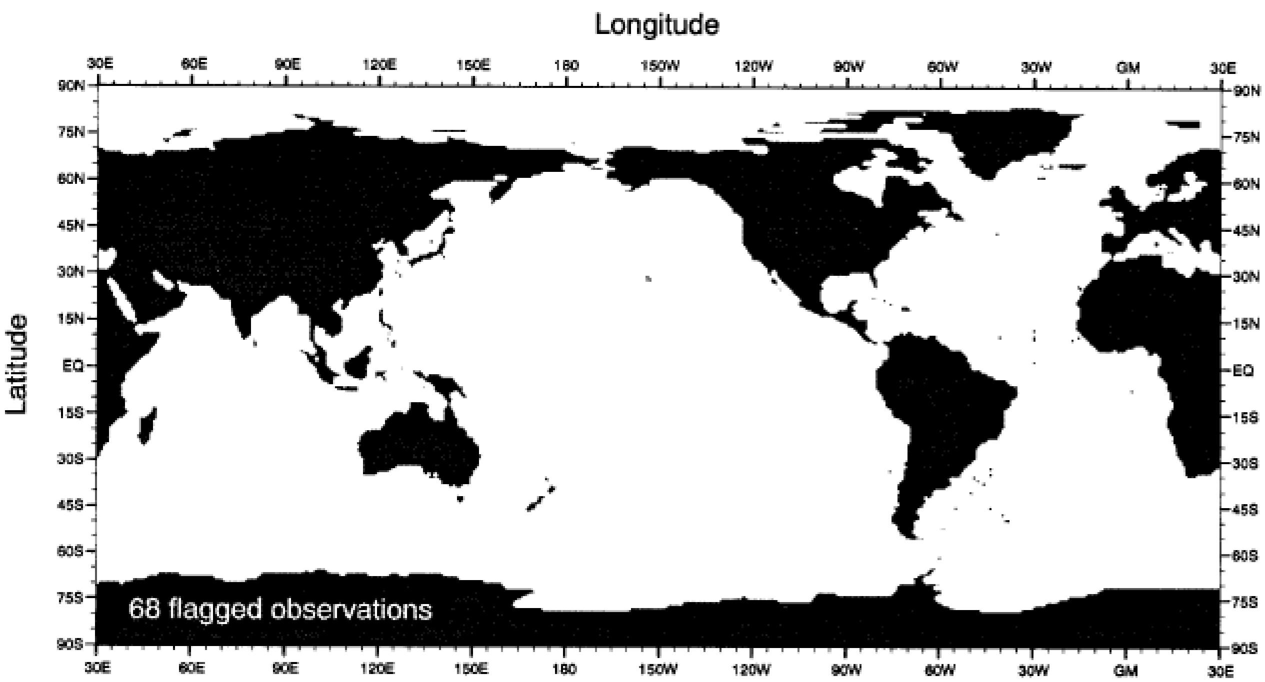


Fig. 12b Location of nitrate statistical check flags in the SD2 file

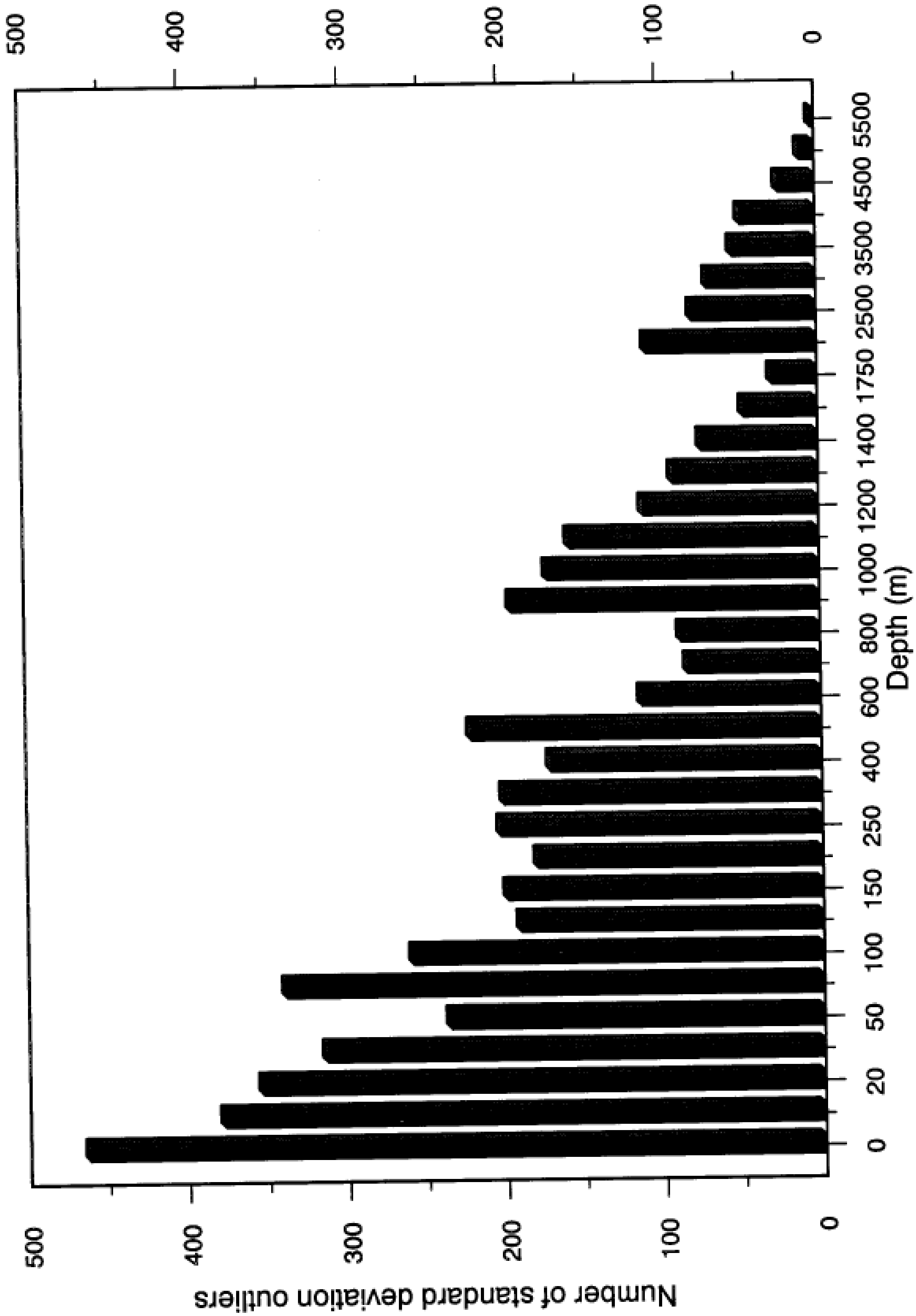


Fig. 13 Nitrate outliers with depth from the standard deviation check

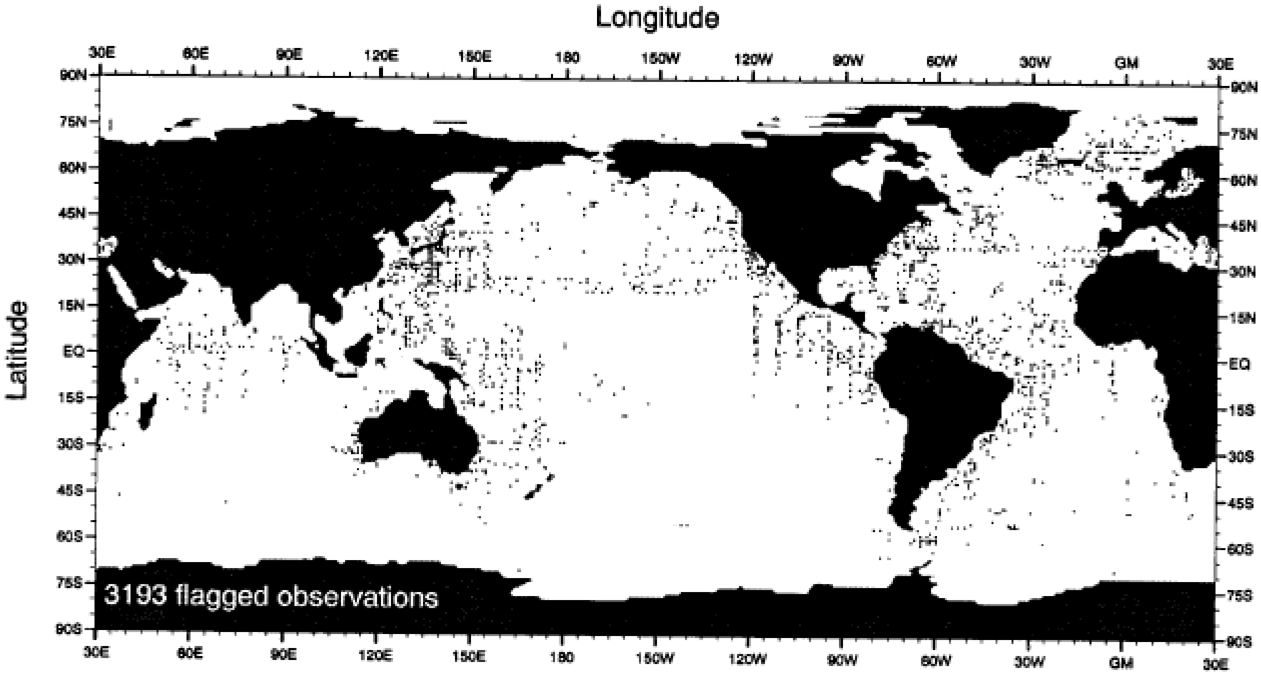


Fig. 14a Location of silicate statistical check flags in the SD file

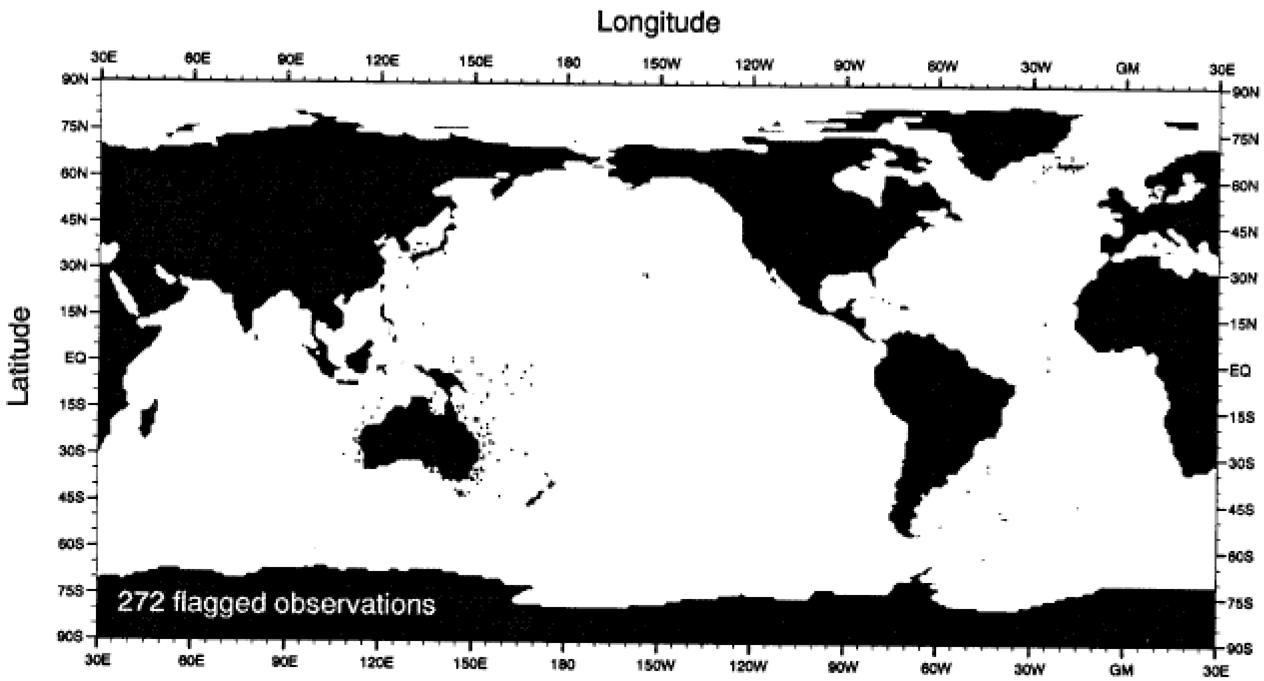


Fig. 14b Location of silicate statistical check flags in the SD2 file

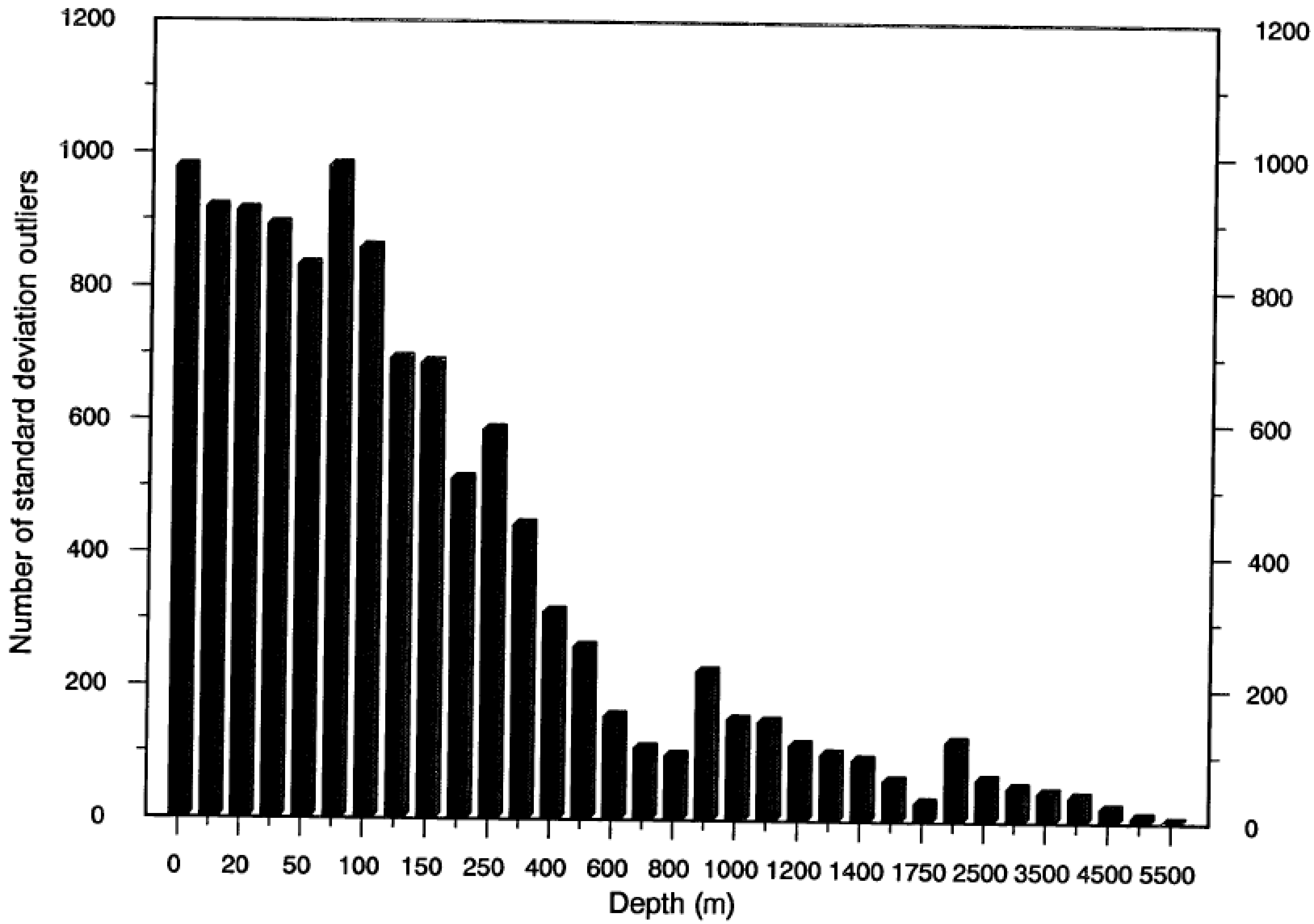


Fig. 15 Silicate outliers with depth from the standard deviation check

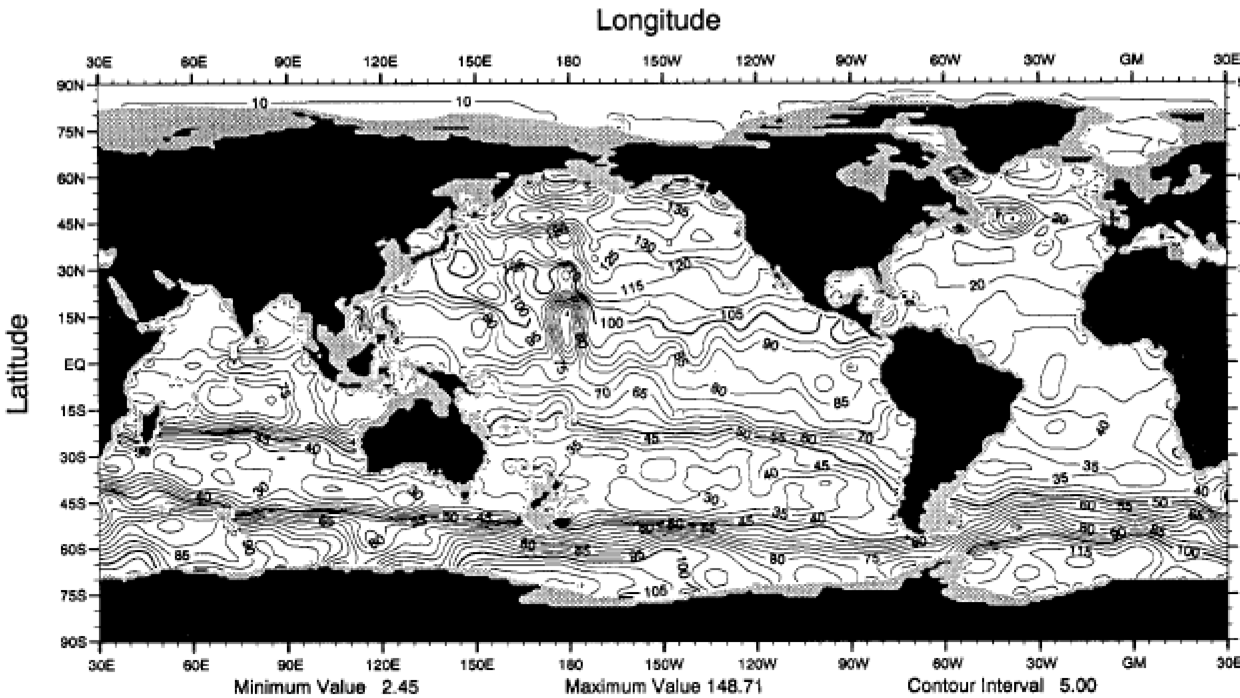


Fig. 16a Silicate annual mean at 1000 m (no check for unrealistic features)

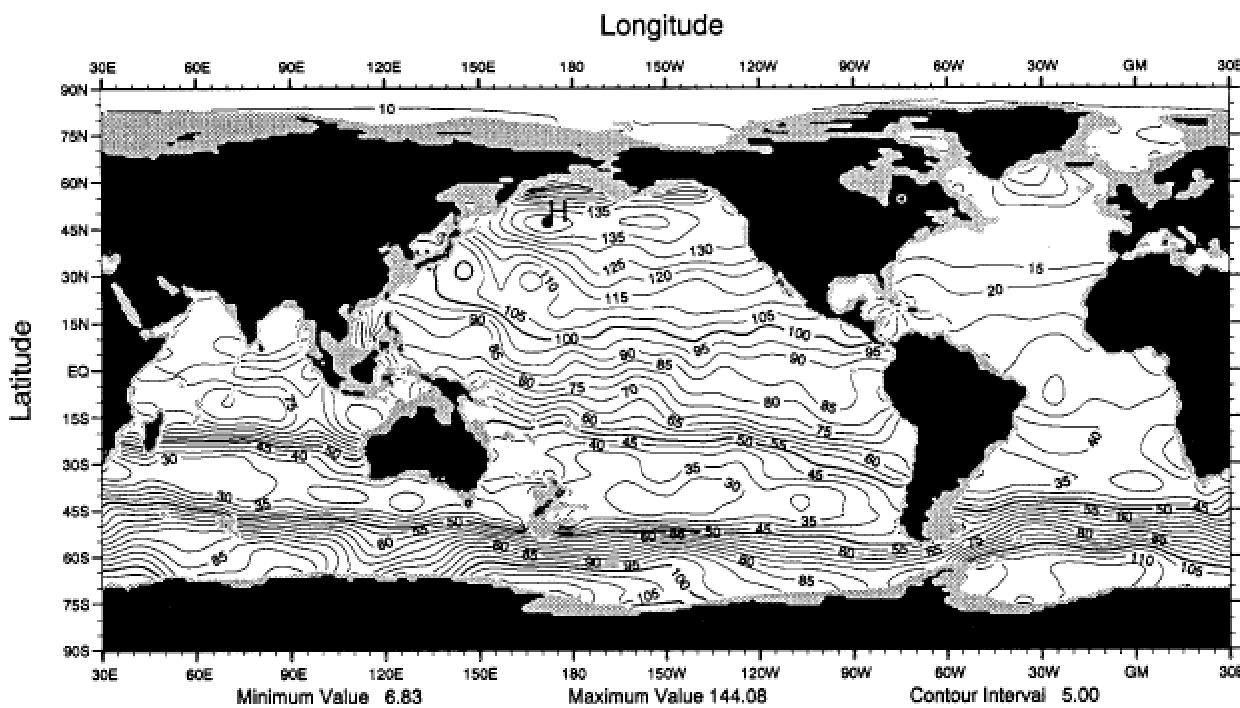


Fig. 16b Silicate annual mean at 1000 m (after check for unrealistic features)

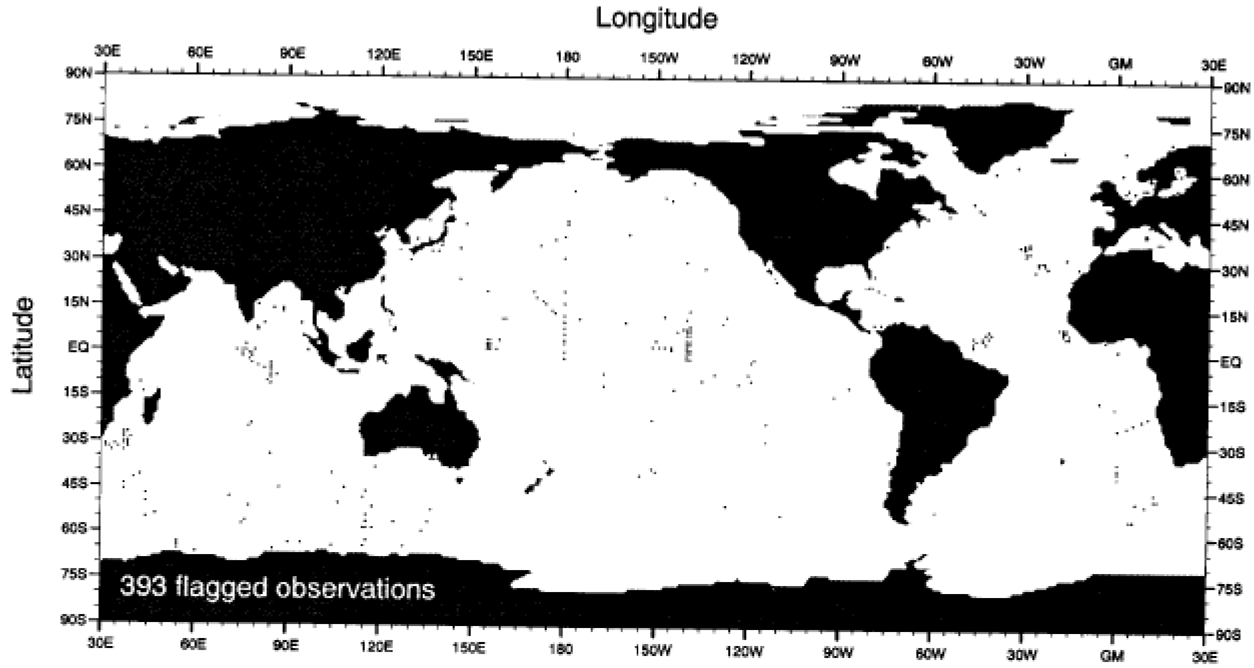


Fig. 17a Phosphate outliers from the unrealistic check of the SD file

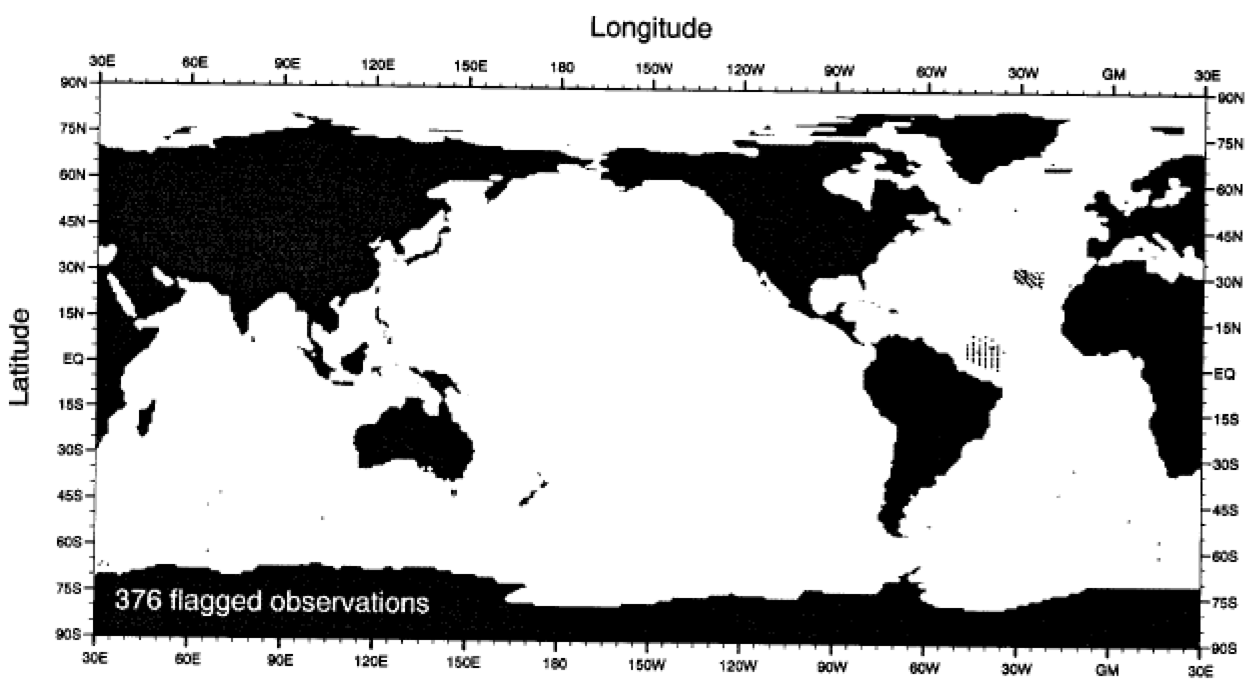


Fig. 17b Phosphate outliers from the unrealistic check of the SD2 file

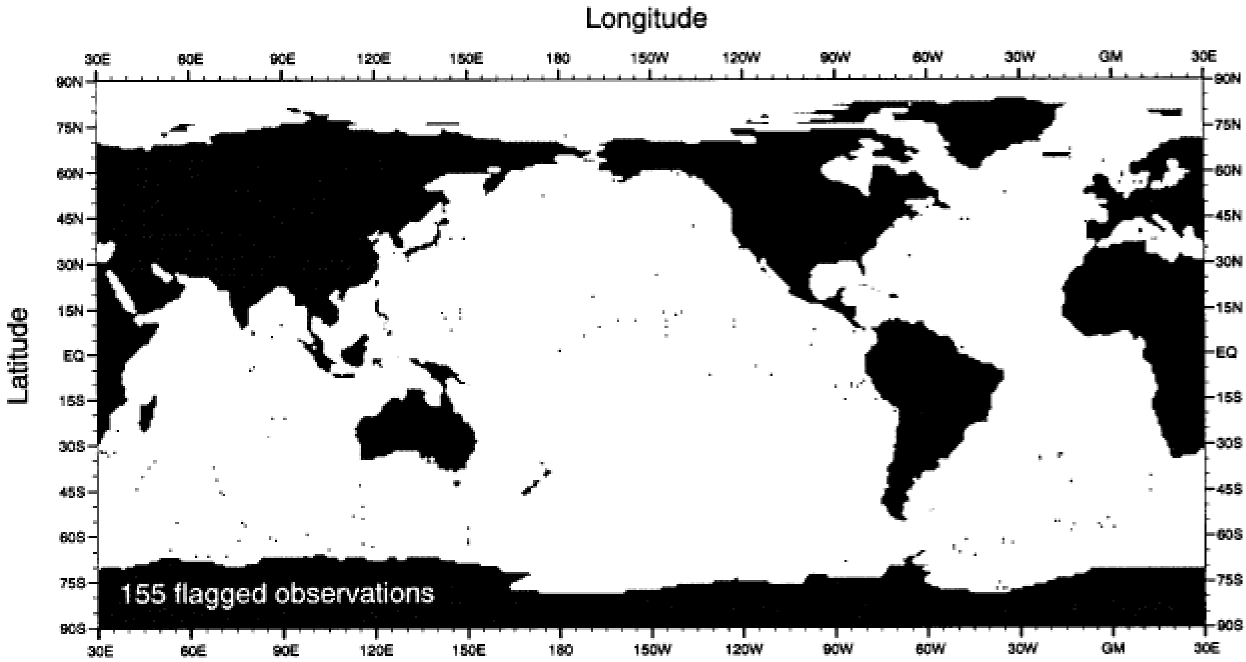


Fig. 18a Nitrate outliers from the unrealistic check of the SD file

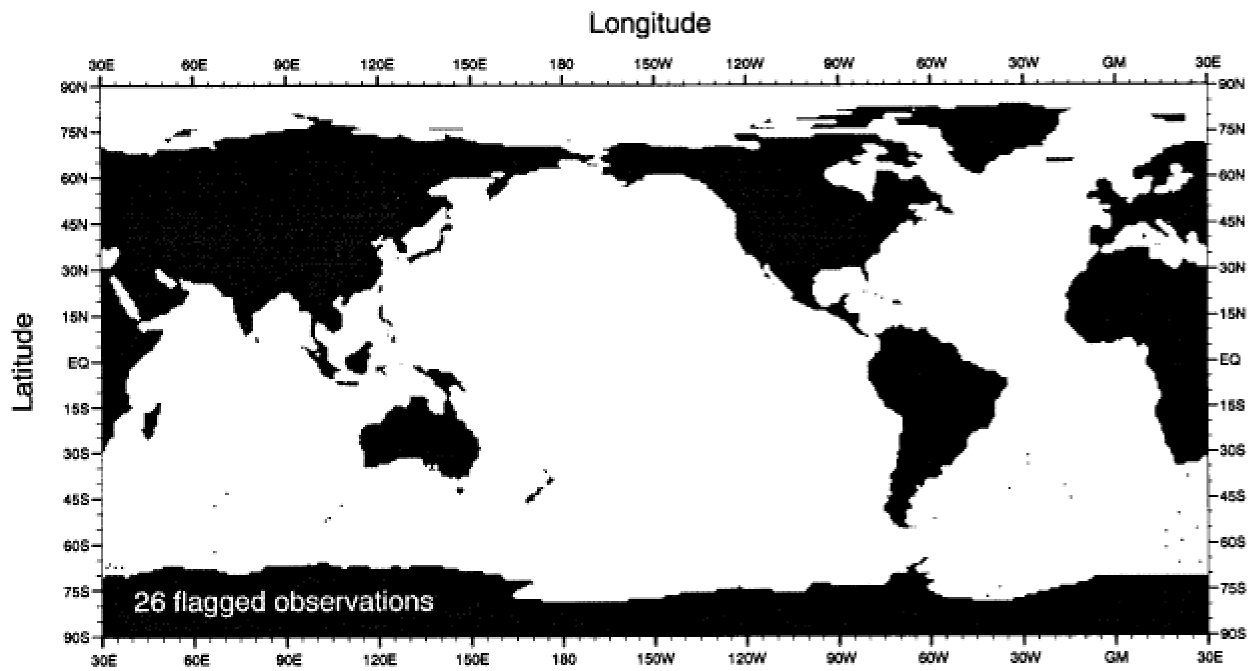


Fig. 18b Nitrate outliers from the unrealistic check of the SD2 file

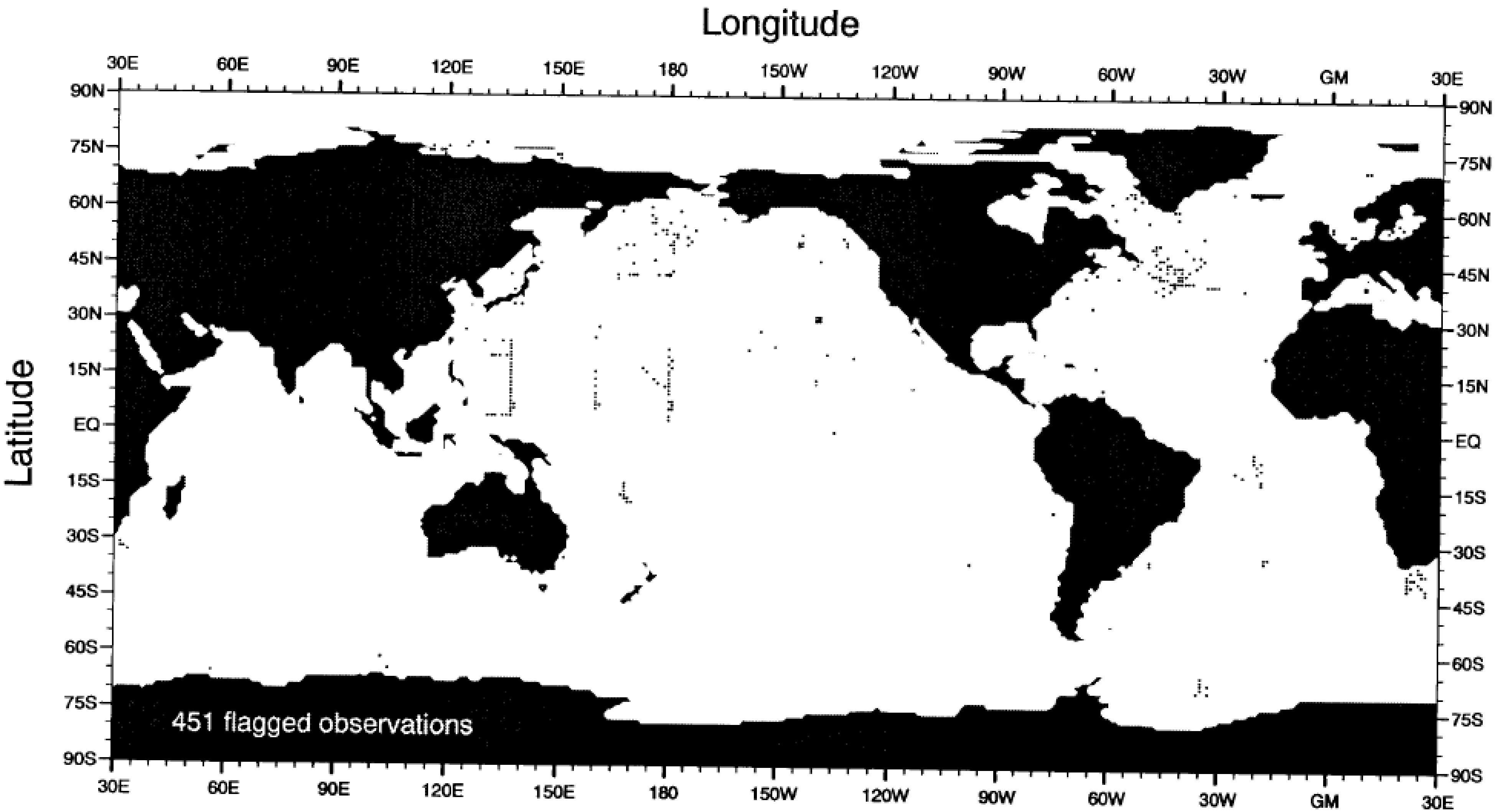


Fig. 19 Silicate outliers from the unrealistic feature check of the SD file