GAO: AN OCEANOGRAPHIC APPLICATIONS MANAGER FOR FISHERIES BIOLOGISTS

Marsac F.[1]

ABSTRACT

This paper is a brief presentation of GAO, software dedicated to processing oceanographic data for the use of fisheries biologists. The system includes the most comprehensive databases possible (multiparameter hydrological stations, vertical temperature profiles, ocean circulation model and pseudo wind stress fields) and Windows software for extracting and carrying out several processes on these databases. The databases cover the tropical Atlantic and the whole Indian Ocean. The goal of GAO is to enable access and processing of oceanographic data on personal computers, and provide the physical background of the pelagic fisheries environment. A new version will be released in 1999 and will be available to the community of fisheries biologists.

RÉSUMÉ

Ce papier est une brève présentation d'un logiciel dédié au traitement de données océanographiques à l'usage des biologistes des pêches. Le système GAO comprend des bases de données aussi complètes que possible (stations hydrologiques multiparamètres, profils verticaux de température, modèle de circulation océanique et pseudo tension de vent) et un logiciel d'extraction et de traitement de ces bases de données. Les bases de données couvrent l'Atlantique tropical et l'intégralité de l'océan Indien. Le but de GAO est de rendre possible sur des ordinateurs personnels l'accès à de nombreuses données océanographiques et leur traitement, de manière à décrire les caractéristiques physiques de l'environnement des pêcheries pélagiques. Une nouvelle version sera produite en 1999 et sera mise à la disposition de la communauté des biologistes des pêches.

Introduction

GAO has been designed to provide to fisheries biologists a comprehensive oceanographic database and standard processing tools in a user-friendly interface. GAO is available on PC and the databases are compressed and organized in a way which allows quick execution of the queries, to be fully operational and convenient for most users.

Great numbers of oceanographic observations are available from the world's oceans. The first problem is the density of the observations, which exhibit a great heterogeneity. Some areas are oversampled, others are almost empty of data. Secondly, it has long been a challenge to compile data from different sources because the data are scattered in different data centres, research organizations and institutes. Furthermore, we often face the problem of different standards (or no standard at all!) for data formats and coding. Facing all these difficulties, many biologists simply gave up, and could not fully explore the environmental context of their fisheries without collaborating with oceanographers. The present GAO version covers both the tropical Atlantic and the Indian Oceans.

This tool could be an effective contribution to carry out some basic analyses relating the trend of high seas resources to the environment.

Data collection and preparation

Various data sources were used to prepare the GAO database. The objective was to gather data from the beginning of the 20th century. Four sources of data can be identified:

- Oceanographic stations
- Vertical temperature profiles
- Pseudo wind stress and

The main characteristics of the databases are summarized in Table 1. The major tasks undertaken in the data preparation are (1) validation and (2) building index tables for quick access to the data.

Oceanographic stations

Data were initially obtained from the U.S. National Oceanographic Data Centre (NODC) and the French Banque Nationale de Données Océanographiques (BNDO) in 1988, when the compilation of the GAO database was initiated. In 1995, after the release of the 1994 World Ocean Atlas of Levitus and Boyer (set of 9 CDs), the whole database was updated to include recent years. At the same time, old data that were not present in the first data sets were made available. The data series covers the period 1906-1994, and is now being updated until 1997 for both oceans.

The parameters included in the database are temperature, salinity, dissolved oxygen, phosphate and nitrate contents, from 0 to 500 m. The data available in the World Ocean Atlas are already validated. Observations are flagged to indicate the degree of confidence on the climatology at different time scales (month, season, year). The flags were kept in the final database, and procedures testing the data to produce the same flag codes are now applied for validating the recent data. The recent data have to be collected from different institutions or research programmes. The Internet provides easy access to these data sets, but we still face the problem of different standards in formats and codes. This task is presently carried out by the GAO database manager.

Index tables were created to link the different segments of the database, header files (for general information) and the core of the data (observations at depth). This means that the database is a closed environment. In the present version, there is no possibility for the user to append new data. The

[1] IRD, BP 5045, HEA, 34032 Montpellier Cedex, France.

database must be considered as an historical reference, up to the recent years. An update is carried out every two years.

Only the western basin (west of 80°E) of the Indian Ocean has been processed for oceanographic stations. This represents more than 13,000 stations, and the yearly distribution is shown in Table 2. The quarterly distribution is given in Figure 1. In the tropical Atlantic Ocean, more than 60,000 stations are included in the database.

Vertical temperature profiles

The first data set, processed in 1988, was provided by the TOGA data centre in Brest, France. The bulk of the data is composed of expendable bathythermograph (XBT) casts, which are launched voluntarily by ships, mostly merchant vessels. The data density is very satisfactory along shipping lines, and this configuration is appropriate for time-series analysis and analysis of anomalies. Other profiles are from CTD casts that are made by research vessels of various research institutions.

In order to have a comprehensive temperature-at-depth database, we extracted from the oceanographic stations database the temperature-depth observations. The old data are dominated by mechanical bathythermographs (MBT) or Nansen bottles. The number of observations in depth is not as large as from XBTs, but the data are more accurate.

In the Indian Ocean, for the 1906-1995 period, the vertical temperature profiles amount to more than 67,000 XBT casts in the area stretching from 30°N to 60°S and 20°E to 120°E. The monthly distribution of the data, by year, is given in Tables 3 to 5, for the three major oceanic areas (West, East and South), and the geographic distribution for some years is plotted in Figure 2. In the Atlantic Ocean, 75,000 profiles are already available for the 1985-97 period alone. The historic data set from the beginning of the century is being integrated.

The validation of the profiles is carried out using two different confidence intervals. From a comparison with a monthly-based climatology, at standard depths, quality flags (1, 3 or 4) are allocated to each temperature at depth (TAD). The confidence levels about the average TAD are as follows:

- for Flag 1 (good quality): 2.5 standard deviations for the 0-125 m layer, and 3 standard deviations for 125-500 m;
- for Flag 3 (doubtful): 3 standard deviations for the 0-125 m layer, and 3.5 standard deviations for 125-500 m;
- for Flag 4 (bad): outside the two confidence intervals

The overall quality flag of the profile depends on the distribution of individual flags at depth. A quality flag of 1 requires 100 % of observations at depth to be flagged 1. If the individual measurements contain some Flag-3 and less than 10 % Flag-4 TADs, the overall flag will be 3. If there are more than 10 % Flag-4s TADs, the profile will be flagged 4. More than 80 % of the profiles in the overall database are Flag-1.

The database structure follows the same rule as the oceanographic station database. An update to 1997 will be carried out for the Indian Ocean in 1999.

Pseudo wind stress

For the Indian Ocean (30°N-30°S / 20°E-120°E), the pseudo wind stress is a model output produced by Florida State University (Stricherz and O'Brien). The data are calculated from ship reports (the most important component of the field data) and some satellite information. The final product is by 1° square and month, since 1970, for the whole Indian Ocean.

For the Atlantic Ocean (30°N-20°S / 15°E-80°W), wind stress is calculated essentially from ship reports. Gridded fields are produced on a 2° square and month basis (Picaut *et al,* 1987)

The pseudo wind stress is the product of the wind vector and the scalar wind. Pseudo stress can be calculated by incorporating two more terms in the product, the drag coefficient and the air density (which can vary according to the area).

OPA circulation model

This model was developed for the Atlantic Ocean by the Laboratoire d'Oceanographie Dynamique et Climatique (LODYC), Paris VI, and is now distributed by Meteo-France. The initial resolution is 0.5° square and 5 days, but we have pooled the data on a 1° square and fortnight basis. For each stratum, temperature, salinity, east-west and north-south components of the current, and vertical velocity at 14 levels from 0 to 450 m are available. The whole tropical Atlantic Ocean (20°N-20°S) is covered for 1980-97.

A similar model has been developed for the Indian Ocean, but it still has to be validated. Therefore, it is not included in the present Indian Ocean part of the GAO database.

Software

The GAO software has a Windows interface (Visual Basic code). The selection of area and time windows are managed by the interface. The queries are then executed by FORTRAN routines.

The software produces two types of output:

- text files (ASCII) and
- maps showing the geographic distribution of the data, with interactive facilities

The text files produced by the software can be imported into spreadsheets or graphics and statistical packages for further processing. A general flowchart of the various procedures is given in Figure 3.

The menu of the main window includes 4 items: oceanographic stations, vertical temperature profiles, other regional, and utilities.

Oceanographic stations and vertical profiles databases:

Two main functions can be executed from these databases:

browse for editing raw data, summary of the density of observations and maps showing the geographic distribution of the stations (profiles). From the map, it is possible to plot a given station (profile) by selecting it with the cursor.

Statistics for computing a set of parameters on each station, and compiling them in strata (1° square-month, time series, space-time diagram). The parameters vary according to the database processed:

- from oceanographic stations: salinity, dissolved oxygen, nitrates and phosphates at levels 0, 100, 200, 300 and

400 m. The levels with the minimum and maximum values of each parameter are also indicated.

- from temperature profiles: temperature at 0 (SST) and 100 m, depth of thermocline (SST-1°C), intensity and depth of the maximal thermal gradient in the thermocline, depth of 23, 20 and 18°C isotherms, and heat content integrated in a given depth range (user-defined).

conversion to transfer the selected data set into another format (CROISIERES) from which additional processing can be made. CROISIERES analysis is included in GAO.

Other regional:

This section includes the processing of the gridded files (OPA and wind stress). The functions include the extraction of data for mapping a given parameter or anomalies to a climatology. It is also possible to create a file with the appropriate format to carry out empirical orthogonal function (EOF) analyses.

From the OPA model, each of the parameters of the database can be extracted at a selected depth level, for a given time stratum (fortnight, month, bimester, quarter, semester, year). From the wind stress, three parameters are available: east-west component (zonal) and north-south component (meridian) of the wind stress, and the associated scalar wind. Negative (positive) values of the zonal component indicate a westward (eastward) flux, and negative (positive) values of the meridian component denote a southward (northward) flux.

Utilities:

This includes the control panel which enables the time and space selection of the processing, an editor to view the text files generated by the different procedures, a contouring facility and a filtering procedure (Hanning low pass cosine filter).

Prospects

Some changes and upgrades are planned for the 1999 version:

1) in the present version, the Indian Ocean is divided into 3 large oceanic zones:
   - West: 30°E-80°E/30°N-30°S
   - East: 80°E-120°E/30°N-30°S
   - South: 20°E-120°E/30°S-60°S

   This is not very convenient when processing areas including 2 large zones. A new configuration of the database is underway, in which the same basic structure will be kept but within 20° boxes instead of large oceanic areas. This will also enable a perfect integration of the two oceans, Atlantic and Indian, for comparative analysis.
2) the oceanographic and temperature profiles databases consist of individual observations at observed levels. It is sometimes necessary to have gridded fields available for the parameters of these data sets, at standard depths. These will be processed and appended to the current data bases. The gridded fields are already available for wind stress and circulation model outputs.
3) the current databases do not include climatological fields like those presented in the 1994 World Ocean Atlas. Climatological data can be computed with GAO on a given selection of years and area. It is still useful to handle the classic data that are referenced in the literature, so the new version will include climatological fields that can be used to calculate anomalies from the observations extracted by a user's query to the GAO database.
4) a circulation model already exists for the tropical Atlantic Ocean (OPA model). A similar model will be validated for the Indian Ocean and will, once available, be integrated under the "Other regional" item of the software. However, it is likely that the 1999 version will not include this model as the validation process might not be completed in the forthcoming months.
5) GAO does not handle surface data sets, already covered by the COADS product. However, the text files generated by the CODE procedure could be processed in different ways within the GAO structure. The new version will include a link between COADS extracted text files and the GAO environment to complement the analyses undertaken on the subsurface parameters.
6) finally, managing a reduced data set of atmospheric parameters (SLP, air temperature,…) collected at land stations, around the oceanic basins can be envisaged. These data can be very useful to define indices in relation to interannual variability, similar to the SOI, through the computation of anomalies.

The release of the new GAO version will be available to the scientific community of tuna researchers, but the potential interest of this database is that extension to other high-seas fisheries is possible. The version should include both Atlantic and Indian oceans in 2 CDs, with data updated until 1997.

Table 1. Characteristics of the GAO databases

Database	Period	Individual observations (no. stations)	Model outputs (stratum size)	Area	Size (Mb)
Indian Ocean					
Oceanographic cruises	1906-1994	13191		30°E-80°E 30°N-30°S	6
Vertical temperature profiles	1906-1995	61044		20°E-120°E 30°N-60°S	25
Pseudo wind stress	1970-1997		1° - month	30°E-120°E 25°N-30°S	17
Atlantic					
Oceanographic cruises	1906-1994	78724			35
Vertical temperature profiles	1985-1997	56780			60
Pseudo wind stress	1964-1997		2° - month		4
OPA circulation model	1980-1997		1° - fortnight		444

Table 2. Monthly distribution of the oceanographic stations 30°E-80°E / 30°S-30°N

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1906	0	0	0	0	1	4	0	0	0	0	0	0	5
1920	0	0	0	0	0	22	30	28	0	0	0	17	97
1921	14	10	0	0	0	17	29	34	19	0	0	0	123
1923	1	0	0	0	11	9	0	0	0	29	38	72	160
1924	12	14	95	17	19	1	0	0	0	0	0	0	158
1928	0	0	0	0	0	0	1	0	1	1	0	1	4
1929	0	0	1	7	2	0	0	4	2	0	1	9	26
1930	11	0	0	0	0	0	0	0	2	0	0	0	13
1932	0	0	0	0	0	3	0	0	0	0	0	0	3
1933	0	0	0	0	0	0	0	0	13	18	19	16	66
1934	4	13	3	7	20	0	0	0	0	0	0	0	47
1935	0	0	0	9	4	0	0	0	0	0	0	0	13
1948	0	0	2	12	73	4	5	0	0	0	0	0	96
1949	16	18	0	0	3	0	0	0	0	0	0	8	45
1950	17	6	29	16	4	9	4	6	0	2	2	0	95
1951	0	12	12	10	0	0	0	2	3	0	23	0	62
1952	0	14	0	18	0	0	0	0	0	0	0	0	32
1955	0	0	0	0	2	0	0	0	0	0	11	0	13
1956	2	9	2	0	9	12	0	0	0	0	0	12	46
1957	2	0	9	0	0	0	0	0	32	78	113	44	278
1958	1	16	10	66	14	44	5	5	24	20	17	9	231
1959	18	34	17	41	31	16	3	4	38	4	14	28	248
1960	25	90	93	45	0	5	26	47	29	0	0	4	364
1961	137	50	74	54	80	21	7	2	2	2	8	2	439
1962	4	2	6	5	10	5	42	73	125	110	78	74	534
1963	127	39	40	15	36	65	109	121	81	89	50	61	833
1964	46	35	74	101	65	74	48	169	73	20	48	53	806
1965	51	59	123	188	150	100	54	19	40	2	4	0	790
1966	56	15	0	0	33	30	51	40	84	64	46	17	436
1967	2	63	20	3	59	19	15	50	39	0	0	0	270
1968	31	71	70	45	25	18	100	198	65	0	73	39	735
1969	23	72	8	37	8	66	0	0	15	89	2	0	320
1970	31	16	18	29	23	79	73	104	101	39	147	52	712
1971	4	92	34	0	96	73	31	41	23	13	71	6	484
1972	15	39	73	80	20	66	75	79	35	23	14	59	578
1973	30	58	92	21	150	116	76	9	9	0	11	10	582
1974	0	41	40	13	38	28	14	3	0	10	7	11	205
1975	42	19	35	12	51	3	10	31	0	1	0	0	204
1976	0	0	1	6	65	18	26	11	0	7	6	0	140
1977	33	54	22	6	0	2	22	28	15	35	15	11	243
1978	11	0	0	18	0	17	0	0	0	0	0	0	46
1979	0	38	8	132	449	250	32	0	0	46	15	1	971
1980	0	7	0	0	48	0	0	37	61	0	7	0	160
1981	4	5	0	7	0	0	0	0	0	7	0	0	23
1982	4	20	0	0	0	27	23	6	29	56	0	20	185
1983	0	0	14	20	0	0	18	64	0	0	0	0	116
1984	0	0	0	0	0	0	0	0	0	1	0	0	1
1985	0	49	34	192	0	0	0	34	0	1	0	0	310
1986	0	1	3	78	3	0	36	12	0	0	0	79	212
1987	126	0	1	0	0	0	129	91	15	58	0	0	420
1988	11	4	0	0	0	0	0	52	4	0	1	2	74
1990	0	0	0	0	0	0	0	0	1	0	0	0	1
1993	0	0	0	0	56	0	0	0	0	0	0	0	56
1994	0	4	14	0	1	0	0	0	0	0	61	0	80
Total	911	1089	1077	1310	1659	1223	1094	1404	980	825	902	717	13191

Table 3. Monthly distribution of the vertical temperature profiles, Area 1: 30°E-80°E/30°S-30°N

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1906	0	0	0	0	0	3	0	0	0	0	0	0	3
1929	0	0	0	2	1	0	0	0	0	0	1	6	10
1933	0	0	0	0	0	0	0	0	0	0	4	7	11
1934	0	13	3	7	0	0	0	0	0	0	0	0	23
1935	0	0	0	2	3	0	0	0	0	0	0	0	5
1948	0	0	2	5	0	0	0	0	0	0	0	0	7
1949	0	0	0	0	2	0	0	0	0	0	0	0	2
1950	0	0	0	0	2	0	0	0	0	0	0	0	2
1952	0	0	0	0	0	0	0	0	0	0	2	0	2
1955	0	0	0	0	0	0	0	0	0	0	6	0	6
1956	0	9	0	0	6	10	0	0	0	0	0	0	25
1957	0	0	6	0	0	0	0	0	0	8	28	0	42
1958	1	1	0	0	6	0	1	0	1	9	1	1	21
1959	0	11	0	0	0	0	0	0	9	0	0	0	20
1960	17	32	26	1	0	0	0	38	33	2	18	17	184
1961	0	0	0	18	0	0	0	0	0	0	0	0	18
1962	0	0	0	0	0	0	23	65	26	8	12	5	139
1963	0	2	28	12	25	10	5	9	51	37	0	16	195
1964	10	9	31	50	28	66	15	103	8	6	0	16	342
1965	40	20	22	55	67	10	1	0	0	0	0	0	215
1966	0	0	0	0	5	13	3	7	7	14	11	1	61
1967	3	14	3	3	4	14	13	10	9	0	0	1	74
1968	31	27	74	12	52	0	53	29	23	0	0	6	307
1969	8	42	44	28	21	21	37	5	37	23	23	21	310
1970	60	41	22	18	20	37	35	104	77	16	81	51	562
1971	4	124	139	9	67	52	26	70	49	28	145	91	804
1972	46	68	142	133	36	35	106	33	33	32	23	52	739
1973	27	20	46	0	77	42	34	0	0	0	0	10	256
1974	0	3	13	13	30	0	0	3	0	10	7	11	90
1975	1	9	25	20	0	0	0	78	7	0	0	0	140
1976	0	0	0	0	0	0	0	0	0	34	81	23	138
1977	0	0	0	0	0	0	0	0	0	0	25	0	25
1978	0	0	67	28	0	0	0	0	1	49	0	0	145
1979	1	2	48	0	87	104	20	0	0	41	18	0	321
1980	117	109	210	111	291	148	292	248	278	123	105	148	2180
1981	167	163	326	439	244	225	157	318	221	229	414	305	3208
1982	197	218	332	275	245	419	238	180	307	225	359	421	3416
1983	211	222	127	204	226	191	88	271	140	335	167	195	2377
1984	229	268	196	159	323	214	144	188	323	223	148	132	2547
1985	123	70	224	260	26	122	103	176	327	228	154	65	1878
1986	109	47	60	197	51	144	99	53	124	195	191	105	1375
1987	193	185	161	140	133	86	198	219	122	151	132	79	1799
1988	134	58	123	166	147	227	86	146	108	178	126	177	1676
1989	112	161	92	183	210	147	187	138	188	135	130	105	1788
1990	128	119	141	173	105	172	129	181	138	167	165	223	1841
1991	174	119	192	127	200	287	193	138	169	127	168	186	2080
1992	163	213	182	105	130	77	169	170	124	214	180	166	1893
1993	151	195	245	121	259	265	324	198	322	268	281	167	2796
1994	138	274	338	438	164	180	165	385	138	255	342	189	3006
1995	150	120	134	156	145	98	84	208	347	229	16	26	1713
Total	2745	2988	3824	3670	3438	3419	3028	3771	3747	3599	3564	3024	40817

Table 4. Monthly distribution of vertical temperature profiles, Area 2: 80°E-120°E / 30°S-30°N (China Sea excluded)

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1970	0	0	0	0	0	0	0	2	0	0	12	23	37
1971	14	14	41	37	28	91	85	43	30	28	36	5	452
1972	16	30	25	22	11	28	9	21	12	17	31	13	235
1975	24	20	20	10	0	0	0	7	50	67	6	0	204
1978	0	29	57	0	0	6	0	3	0	0	0	0	95
1980	0	0	0	0	0	1	0	0	0	0	0	0	1
1981	0	0	1	0	0	0	0	0	0	0	0	0	1
1982	0	1	0	0	1	0	8	0	0	0	0	0	10
1983	0	0	0	0	0	0	0	1	0	1	1	1	4
1984	0	0	0	0	0	0	38	47	0	1	2	0	88
1985	143	205	39	4	61	171	26	17	98	213	101	44	1122
1986	0	0	0	0	0	2	0	19	0	0	0	0	21
1987	0	0	167	12	0	0	0	0	0	0	4	0	183
1988	0	21	33	1	0	5	9	37	0	16	28	2	152
1989	73	104	144	116	148	135	165	105	70	80	106	103	1349
1990	76	84	133	175	126	183	143	135	103	203	132	124	1617
1991	67	121	166	193	153	151	116	109	139	96	102	121	1534
1992	103	146	105	93	99	57	89	148	86	222	120	127	1395
1993	94	138	120	128	167	81	129	137	201	135	259	158	1747
Total	610	913	1051	791	794	911	817	831	789	1079	940	721	10247

Table 5. Monthly distribution of the vertical temperature profiles, Area 3: 20°E-120°E / 30°S-80°S

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1906	0	0	0	3	3	0	0	0	0	0	0	0	6
1917	1	0	0	0	0	0	0	0	0	0	0	0	1
1926	0	0	7	0	0	0	0	0	0	0	0	0	7
1929	0	0	0	0	0	0	0	0	0	0	0	7	7
1930	15	5	6	0	0	0	0	0	13	0	0	0	39
1931	2	5	2	0	9	0	1	0	0	0	0	0	19
1932	0	0	0	20	16	0	0	0	0	0	0	0	36
1933	0	0	0	0	0	0	0	0	0	0	0	3	3
1934	16	0	0	0	17	0	0	0	0	0	0	3	36
1935	6	8	6	7	0	0	0	0	0	0	17	2	46
1936	9	8	12	16	6	0	0	0	0	0	0	2	53
1937	5	0	0	0	0	0	0	0	0	0	10	16	31
1938	10	0	0	1	0	0	3	4	0	1	4	3	26
1939	0	1	0	0	0	0	0	0	0	0	0	0	1
1947	27	291	51	0	0	0	0	0	0	0	6	8	383
1948	28	0	0	6	6	0	0	6	0	0	0	6	52
1949	0	0	0	6	0	6	6	0	0	0	6	0	24
1950	0	6	2	3	0	6	0	7	21	5	0	0	50
1951	24	18	0	1	6	6	8	10	3	3	2	0	81
1954	3	3	2	3	1	3	2	3	9	3	2	2	36
1955	2	8	3	1	6	2	7	2	3	2	4	2	42
1956	11	7	36	1	32	1	2	4	3	4	4	7	112
1957	131	128	60	49	7	10	7	0	6	0	0	5	403
1958	63	279	49	151	34	2	1	34	2	2	1	5	623
1959	16	99	11	0	13	60	24	0	18	15	28	100	384
1960	344	555	116	12	12	52	34	21	14	13	23	137	1333
1961	46	85	64	123	20	18	42	17	21	34	22	46	538
1962	33	32	85	80	15	136	120	30	36	71	160	30	828
1963	62	46	21	62	52	45	76	23	168	21	73	16	665
1964	46	39	47	61	17	20	47	55	50	23	15	20	440
1965	55	20	50	20	66	124	369	26	15	39	1	47	832
1966	21	18	78	23	32	22	11	15	15	16	28	46	325
1967	30	70	23	22	16	10	41	27	27	20	75	63	424
1968	16	22	53	26	26	16	9	37	95	91	56	43	490
1969	40	55	157	43	19	33	49	32	70	109	24	67	698
1970	23	32	42	40	15	19	36	99	53	147	115	109	730
1971	32	197	328	100	33	68	178	190	186	218	215	50	1795
1972	62	56	42	52	34	99	150	49	53	55	8	126	786
1973	52	120	105	6	27	15	101	52	15	13	142	51	699
1974	307	241	127	12	3	1	38	10	6	62	8	11	826
1975	14	39	36	23	11	16	0	5	22	31	43	34	274
1976	1	18	68	24	62	21	23	6	6	25	19	17	290
1977	71	21	13	0	30	1	0	0	35	22	2	11	206
1978	4	2	10	16	1	1	0	4	0	7	1	21	67
1979	42	41	21	25	7	0	0	1	0	6	4	14	161
1980	15	26	10	13	7	4	1	21	12	0	2	32	143
1981	7	4	25	4	19	0	8	1	4	1	0	7	80
1982	2	2	21	1	0	0	3	1	7	2	79	21	139
1983	42	19	46	17	12	13	7	1	8	7	19	9	200
1984	1	3	21	26	1	3	10	17	9	11	3	0	105
1985	20	4	10	12	12	6	9	4	8	1	2	28	116
1986	26	7	25	17	4	4	47	2	16	24	0	23	195
1987	9	16	37	43	9	11	5	36	151	6	3	34	360
1988	37	57	3	59	4	2	1	2	4	0	25	0	194
1989	1	10	15	1	16	2	5	6	31	47	88	26	248
1990	8	22	17	2	1	4	3	6	12	1	11	22	109
1991	26	11	0	0	0	0	0	0	0	0	0	0	37
1992	0	0	0	0	0	0	0	0	0	0	0	4	4
1993	0	0	35	4	0	6	0	0	27	0	8	0	80
Total	1864	2756	1998	1237	739	868	1484	866	1254	1158	1358	1336	16918

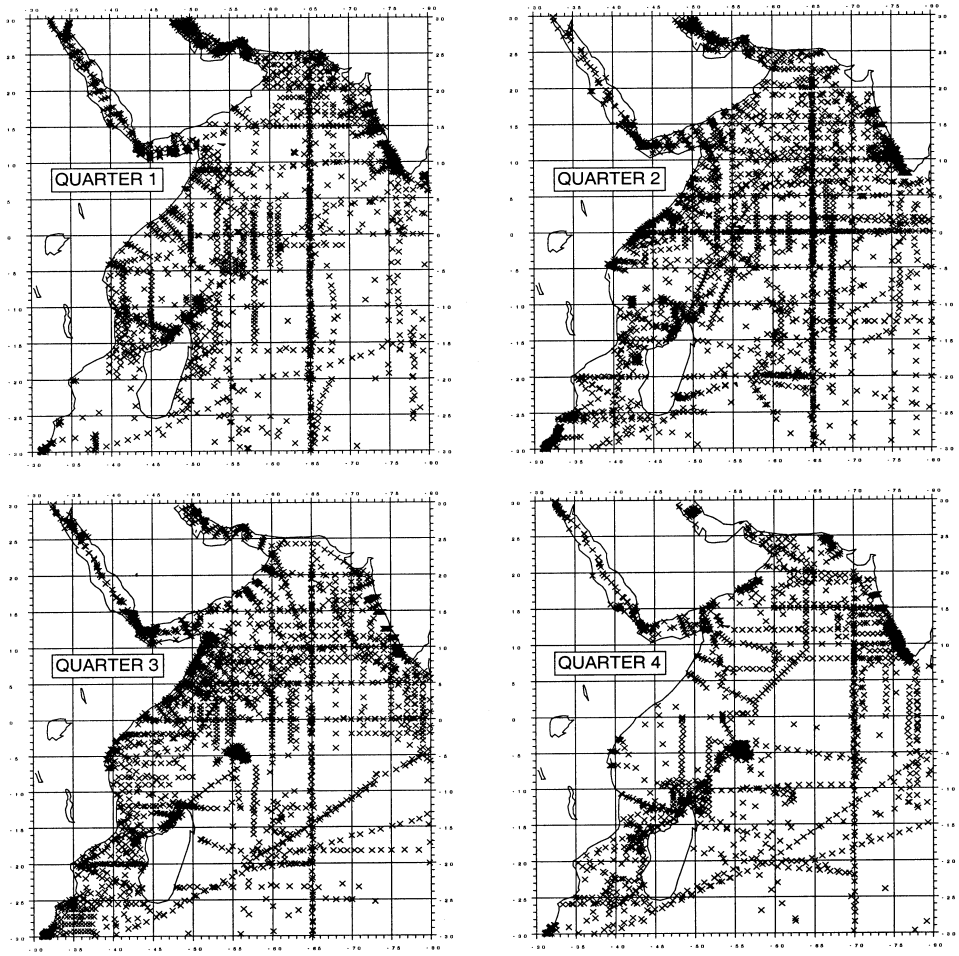

Figure 1 – Quarterly distribution of the hydrological stations in the Western Indian Ocean, 1906-1994.

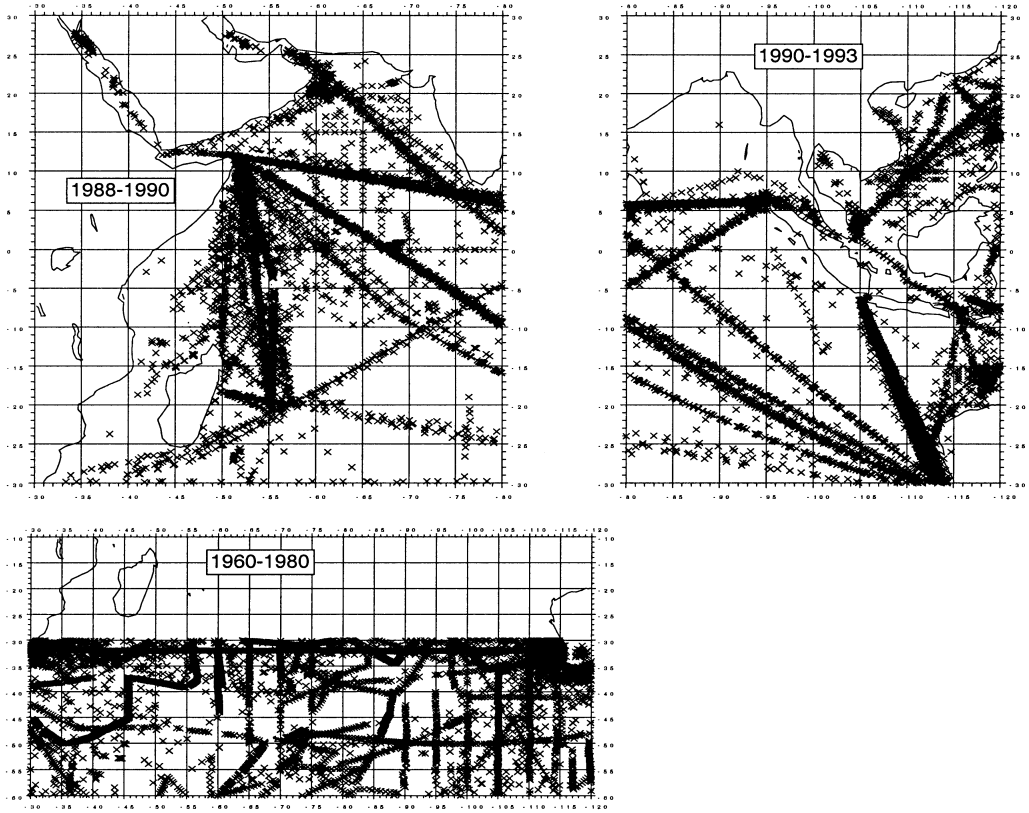

Figure 2 – Distribution of temperature profiles in the three large oceanic zones. Some years are selected to provide an idea of the general distribution.

Figure 3: Flowchart of the GAO software

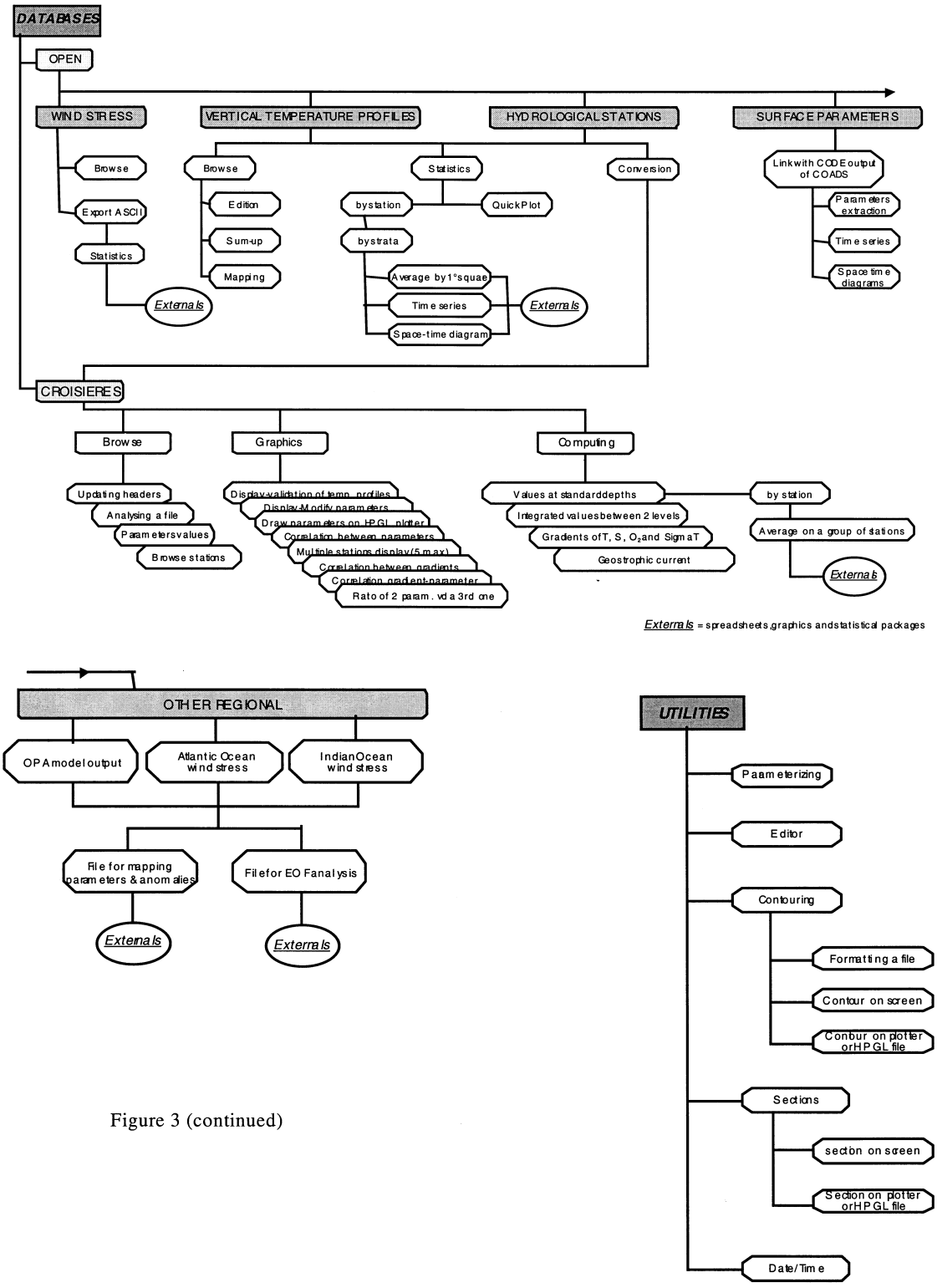

Figure 3 (continued)