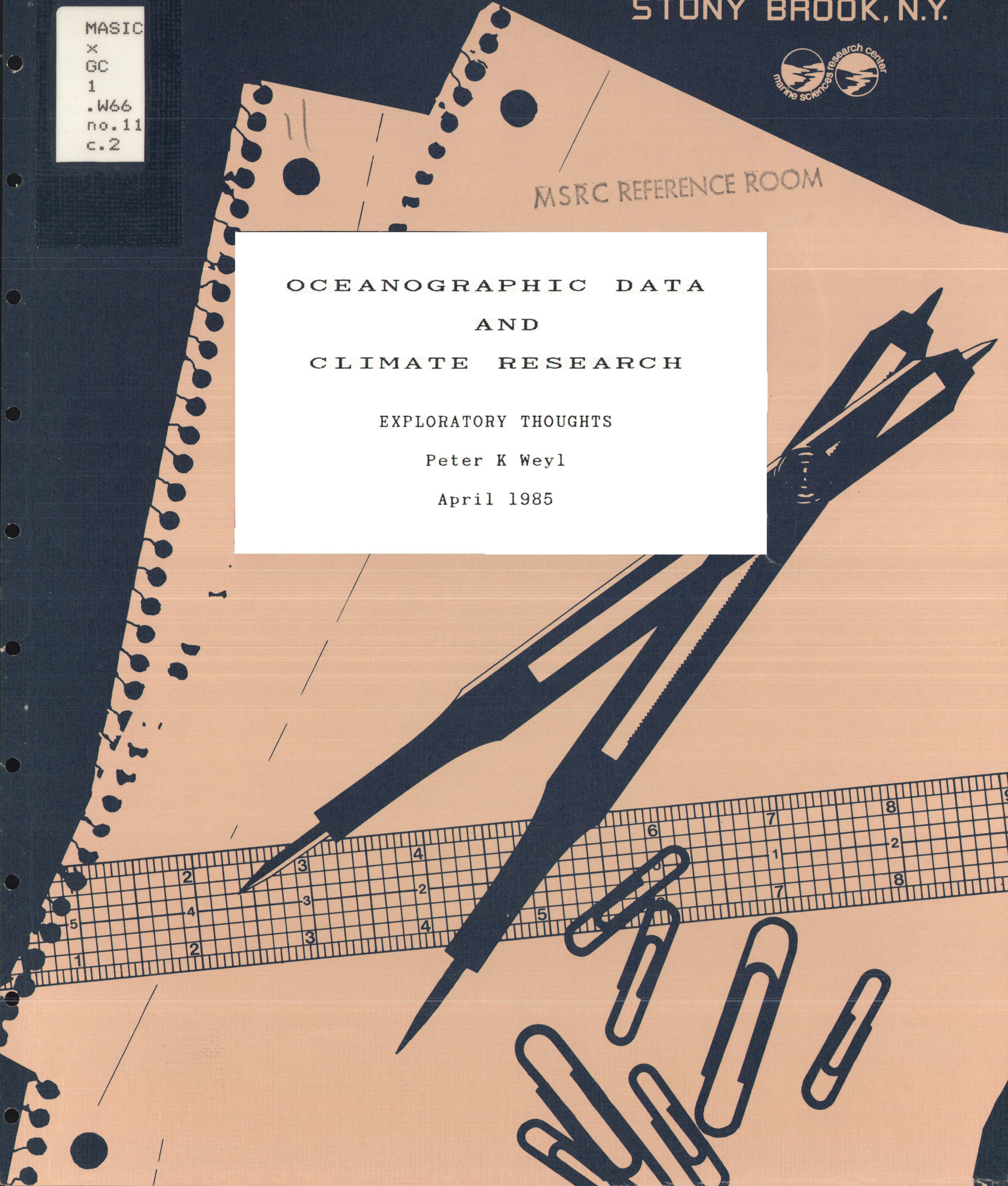
MARINE SCIENCES RESEARCH CENTER
STATE UNIVERSITY of NEW YORK
STONY BROOK, N.Y.

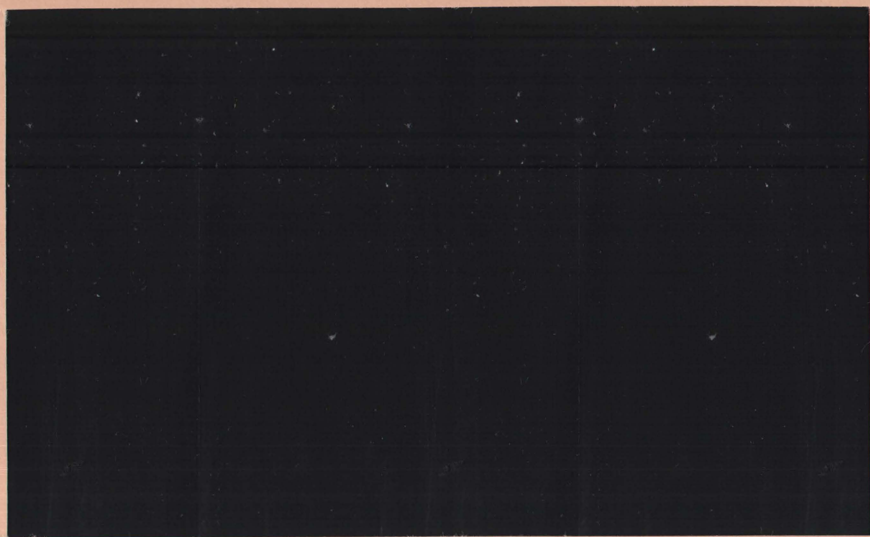


OCEANOGRAPHIC DATA AND CLIMATE RESEARCH

EXPLORATORY THOUGHTS

Peter K Weyl

April 1985



Marine Sciences Research Center, SUNY at Stony Brook

OCEANOGRAPHIC DATA
AND
CLIMATE RESEARCH

EXPLORATORY THOUGHTS

Peter K Weyl

April 1985

A Report in the Coastal Ocean Sciences and Management (COSMA) Program Series

Working Paper # 11

Ref. # 85-1

Approved for Distribution

J. R. Schubel

1. Oceanographic Data

1.1 Oceanographic Data Ignored

In reading and hearing about recent major climate research projects I have been disturbed by the quality of the oceanographic input to such efforts. They seem to focus on variables that are easy to measure and ignore essential parameters. The interaction between the ocean and the atmosphere connects two reservoirs having very different time constants. The sea surface temperature is usually considered as a lower boundary condition for the atmosphere. The crucial factor however is the response of the intensive characteristics of the surface ocean to fluxes of heat, water and chemical substances (eg. CO_2).

The response of the surface ocean to exchange with the atmosphere depends primarily on the thermo haline structure of the ocean. For example, the heat loss per unit area required to form sea ice can vary by many orders of magnitude. A shallow halocline results in the formation of sea ice near Greenland, while the largely isohaline eastern Greenland-Norwegian Sea remains ice free. The difference in haline structure between the North Atlantic and the North Pacific led me to propose a mechanism for the initiation of the ice ages (Weyl 1968).

The thermo-haline structure near the ocean surface is largely ignored by current climate research because:

1. Salinity is not a meteorological variable
2. Surface salinity can not be determined by remote sensing
3. It is very expensive to determine the thermo-haline structure near the sea surface
4. It is virtually impossible with even large resources to monitor the change in the thermo-haline structure over time and space
5. Significant changes in the thermo-haline structure occur primarily under weather conditions that preclude direct shipboard observations

1.2 Data and Information

The National Oceanographic Data Center is a valuable storehouse of data on the time space variations of oceanographic parameters. The problem we face is how to convert these data into information relevant to climatic change. To be useful, information must interact with the thought processes of the climate researcher. Two types of oceanographic information products are currently available:

1. Atlases showing oceanographic parameters as observed during major ocean expeditions, eg: the GEOSECS Atlases issued by the National Science Foundation

2. Atlases based on large data sets that summarize average conditions of individual ocean basins or the World Ocean, eg: the recent Climatological Atlas of the World Ocean (NOAA Professional Paper No 13. by Levitus)

These products are useful for obtaining an overview of oceanographic conditions. They provide a picture during the space-time frame of an expedition and a statistical average of objectively analyzed data. Climatologically significant conditions, however, seldom coincide with times of observation and differ from statistical averages. Horizontal boundaries between water types tend to be sharp but variable in location. Boluses of anomalous water types are often trapped in other waters. A good example of the effect of horizontal resolution in depicting water properties is offered in the Fuglister Atlas (1960). Compare the sharp boundaries of the cold core eddy at 40 North, 45 West as depicted by the high resolution bathythermograph data (pg. 15) and by the low resolution hydrographic data (pg.41). Internal waves give rise to vertical oscillations of the water. Because of the nature of waves, randomly timed samples are more likely to occur when the wave is near its extreme displacement than when the displacement is small. As a result, isolines in the first type of altlases display meaningless vertical oscillations.

1.3 A New Approach to Oceanographic Data

To deal with climatic change, we must look at existing oceanographic data, not as fixed values, but rather as parameters that change in response to the exchange of heat, water and chemicals and as a result of biological processes. Using our knowledge of the orders of magnitude of such processes, we can numerically simulate the resultant changes of the characteristics of the ocean and its interface with the atmosphere. Such simulations can never prove that specific conditions were actually produced by the assumed forces. However, simulations can identify mechanisms that are inadequate to make a contribution.

Simulations of oceanic processes acting on observed values of oceanic parameters can help us identify times, locations and mechanisms that may be important in climatic change, processes that alter the content of heat and/or chemical substances of the ocean in excess of the normal seasonal cycle. The results of such simulations can then be the basis for planning observational programs that test the proposed models and improve our knowledge of the inferred quantitative relationships. They can assist us in designing monitoring programs to help predict future climatic change. They help replace statistically inferred correlations by a mechanistic understanding of ocean atmosphere interactions.

2. The Microcomputer, a New Thinking Tool

The scarcity of simulation studies in the past is in part a result of the large effort required to carry out the needed computations and the difficulties of translating the output into comprehensible formats. Recent advances in microcomputer hardware and software have revolutionized our ability to carry out simulations. Complex interactive analyses of oceanographic data can be carried out rapidly and the investigator can scan a variety of graphical outputs almost instantaneously to facilitate thinking constructively about the results.

Recently, I have been exploring the power of these tools for analyzing oceanographic data. To use microcomputers effectively for the analysis of oceanographic and climatic data, one must develop integrated Information Systems.

2.1 Applications Program Based Information Systems

Prior to the availability of powerful microcomputer applications programs, information systems depended on the development of adequate programs using one of the computer languages such as BASIC, Pascal or Fortran. The development of such programs required skilled programmers and the resultant systems were difficult to adapt to changing needs. Programming with applications programs is much easier, the required skills can be learned in a few weeks rather than a few years. Further, the resultant systems can easily be modified and enhanced. Using Lotus 1-2-3 and more recently Lotus Symphony, graduate students without previous computer experience have been able to learn to develop complex information systems in a few weeks. The use of the new generation of software will revolutionize the analysis of environmental data.

A new technology, the use of laser disks to store very large data files (several hundred megabytes) on inexpensive optical disks for use in microcomputers will be available within a year. This will provide an ideal format for information products from environmental data centers. The integration of these files into microcomputer based information systems will provide powerful new tools to deal with the complex problems of environmental and climatic change. I have begun development of the following information systems:

1. A World Ocean Chemistry Information System for information about the "non-seasonal" ocean below 200 meters. The system is designed to provide quantitative information about the chemical characteristics of the World Ocean in order to enlarge our understanding of oceanographic processes.

2. An Ocean Surface Information System to provide information about the variable surface layer of the ocean. This system develops indices of the surface oceans responsiveness to atmospheric forcing and methods to simulate ocean atmosphere interaction.

oceanographic and climate research. The new microcomputer tools can greatly increase the power of scientific analysis. They will also create a demand for new types of products from environmental data centers.

The scientific information systems I am working on are an outgrowth of several years of experience developing Management Information Systems for Coastal Zone Management. With funding from NODC and the William H. Donner Foundation, we have developed a system for the Port of New York and New Jersey and with funding from the Maritime Administration we have developed a system for the Port of New Orleans. Both these systems are available at NODC (contact Jim Audet). The management systems use the Lotus 1-2-3 software operating on an IBM Personal Computer XT.

3. The World Ocean Chemistry Information System

The purpose of this system is to provide a quantitative inventory of the chemistry of the world ocean. The system is an elaboration of the Temperature - Salinity Statistics of the World Ocean pioneered by Montgomery (1985). The statistics are limited to the ocean below 200 meters, to reduce seasonal variability. The GEOSECS data set provides a comprehensive overview. Worksheets have been developed to decompose individual station data into averages over T-S classes using the following class boundaries for potential temperatures (T) and salinity (S):

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	
T:	-2	0	1	2	3	4	6	8	10	12	14	16	18	20
S:	30	32	34	34.2	34.4	34.6	34.7	34.8	34.9	35.0	35.2	36		

A class designation of 207 implies that the potential temperature is equal to or greater than 0 and less than 1 degree and that the salinity is equal to or greater than 34.7 and less than 34.8 ppt.

For a preliminary survey of the chemical compositions of the world ocean, a total of 38 GEOSECS stations covering the extremes of chemical composition have been entered. Each class is further subdivided to isolate separate water volumes in the same T-S class and to separate connected water volumes with distinct water chemistry.

A printout of part of the listings sorted by T-S class is shown as Table 1. The location column (A) indicates the ocean area, 100 for the Southern Ocean, 210 for the South Atlantic and so on. Each row represents vertically averaged data for one station over a layer whose vertical extent is given in column D and the average elevation of the layer is given in column M. Columns A through L are obtained directly from the GEOSECS data. Column N is the computed solubility of oxygen at one atmosphere for the average T and S of the layer. Column O, the O2 loss is the difference between oxygen saturation and the observed average concentration of dissolved oxygen. Additional columns that are functions of the observed parameters, for example the nitrate to phosphate ratio (column Q) can readily be added.

Table 1 GEOSECS Data arranged by T-S Class

Loct	Stn #	Class	Layer in m	Pot T deg C	Sal ppt	D O uM/kg	SiO3 uM/kg	PO4 uM/kg	NO3 uM/kg	Alk uE/kg	T CO2 uM/kg	Avg z m	O2SOL uM/kg	O2 LOSS	TCO2 -O2L	N/P
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
320	328	306	1822	1.494	34.676	151	135.3	2.42	37.0	2424	2338	-1514	321	170	2168	15.3
100	76	306	200	1.952	34.696	181	87.5	2.20	32.7	2361	2255	-243	317	136	2119	14.8
100	87	306	86	1.019	34.674	203	107.8	2.19	32.3	2357	2256	-1415	325	122	2134	14.7
320	343	306	2235	1.416	34.669	125	161.0	2.59	38.1	2436	2373	-484	322	197	2176	14.7
100	430	306	287	1.890	34.658	176	87.0	2.30	33.8	2346	2276	-384	318	142	2134	14.7
330	214	306	3251	1.545	34.667	134	162.1	2.53	37.2	2435	2365	-2693	321	187	2178	14.7
310	303	306	461	1.845	34.668	161	112.5	2.37	35.2	2406	2325	-2899	318	157	2168	14.9
330	219	306	1582	1.417	34.645	87	219.1	2.85	39.5	2451	2406	-3103	322	235	2171	13.9
320	246	306	2119	1.420	34.671	143	145.5	2.48	37.2	2442	2367	-2985	322	179	2188	15.0
330	223	306	3852	1.214	34.672	144	151.9	2.48	37.3	2436	2358	-3126	324	180	2178	15.0
100	432	306	181	1.427	34.659	196	88.1	2.23	32.5	2356	2278	-3680	322	125	2153	14.6
100	287	306	161	1.087	34.680	204	95.9	2.14	32.2	2368	2265	-2936	325	120	2144	15.1
310	321	306	1604	1.507	34.678	165	121.5	2.34	35.4	2408	2321	-4205	321	156	2165	15.1
330	347	306	2289	1.438	34.670	117	167.0	2.63	38.4	2438	2371	-3142	322	204	2166	14.6
431	413	307	371	1.800	34.764	137	140.4	2.55	35.6	2440	2363	-2213	319	181	2182	14.0
420	425	307	1865	1.505	34.732	170	126.2	2.35	33.8	2404	2318	-1839	321	151	2167	14.4
410	435	307	995	1.500	34.742	197	99.9	2.14	31.3	2367	2275	-2514	321	124	2152	14.6
100	91	307	1102	1.498	34.734	202	93.1	2.12	30.2	2362	2247	-1670	321	119	2128	14.3
410	453	307	1974	1.349	34.728	188	115.2	2.20	32.6	2390	2296	-1152	322	135	2161	14.8
100	430	307	1049	1.493	34.736	198	96.0	2.11	31.3	2355	2267	-889	321	123	2144	14.8
420	420	307	1825	1.437	34.735	165	131.9	2.38	34.1	2417	2333	-3415	322	157	2176	14.3
210	61	307	367	1.353	34.770	218	88.7	1.97	28.5	2322	2238	-4060	322	104	2134	14.4
100	280	307	1236	1.499	34.730	197	98.8	2.07	31.2	2375	2294	-3335	321	124	2170	15.1
310	303	307	823	1.361	34.722	194	105.0	2.20	32.2	2371	2305	-3874	322	128	2177	14.7
420	438	307	1483	1.408	34.725	175	123.1	2.33	33.5	2395	2310	-3038	322	147	2163	14.4
410	428	307	1038	1.531	34.748	203	97.2	2.08	30.5	2367	2275	-2893	321	118	2156	14.6
100	76	307	1198	1.416	34.717	192	103.3	2.18	32.0	2372	2263	-3164	322	130	2132	14.7
100	432	307	828	1.358	34.727	200	98.6	2.15	31.4	2356	2280	-3308	322	122	2157	14.6
431	416	307	650	1.676	34.755	118	149.6	2.62	36.8	2458	2388	-3029	320	202	2187	14.1
310	321	307	346	1.056	34.702	187	121.1	2.24	33.9	2402	2321	-3000	325	138	2183	15.1
210	103	307	250	1.244	34.775	223	91.7	1.96	28.2	2381	2257	-2629	323	100	2158	14.4
100	287	307	348	1.143	34.721	193	105.9	2.14	32.4	2371	2276	-2883	324	131	2145	15.2
432	446	307	992	1.568	34.737	140	146.3	2.51	35.8	2435	2359	-2825	320	180	2179	14.2
230	121	308	910	1.873	34.891	270	33.7	1.25	18.8	2343	2185	-3176	318	47	2138	15.0
210	61	308	111	1.854	34.813	223	70.4	1.80	26.2	2350	2224	-3714	318	95	2129	14.6
230	31	308	2178	1.684	34.866	255	51.2	1.50	22.2	2360	2222	-4299	319	64	2158	14.8
220	39	308	996	1.627	34.859	258	50.4	1.44	21.7	2354	2202	-4596	320	62	2140	15.0
210	103	308	440	1.745	34.829	231	68.2	1.75	25.4	2374	2239	-2304	319	87	2152	14.5
220	109	308	1104	1.840	34.869	248	51.3	1.49	22.7	2350	2206	-4950	318	70	2136	15.2
230	115	308	758	1.953	34.887	249	48.7	1.50	22.1	2364	2211	-4934	317	68	2143	14.7
230	11	308.1	193	1.335	34.882	299	8.3	0.92	14.3			-4478	322	23		15.6
230	11	309	35	1.868	34.903	292	10.2	0.98	14.9			-2190	318	26		15.2
241	15	309	119	1.060	34.926	303	6.5	0.80	13.2			-277	324	21		16.4

The listing can be resorted to find areas in the ocean where specific parameters are anomalous. Alternatively, one can use the data query facilities of the Lotus Symphony worksheet to find all segments where specified parameters have particular values. Selected parameters from selected stations can also be shown in graphical form.

For example, I have been interested in the problem of the storage of excess CO2 in the ocean. Because they are invariant to temperature changes and vertical displacements, alkalinity and total CO2 are useful descriptors of the CO2 system. However, in the sea, the alkalinity and total CO2 are altered by carbonate precipitation and dissolution and by the oxidation and production of organic matter. If one modifies the total CO2 concentration by using up all the alkalinity to precipitate carbonates and restores the dissolved oxygen concentration to saturation with the atmosphere at 1 bar, one obtains a parameter that is essentially invariant to these processes. A parameter, the "CO2 index" is defined by the following equation:

CO2 Index = Total CO2 - Alkalinity/2 -(O2 at saturation -Actual O2).

The distribution with depth of this "CO2 Index" for all T-S classes from the selected GEOSECS stations is shown in Figure 1. The index ranges from a low of 830 to a high of 1012 micromoles/kg. The low value is for Red Sea Water, in the open ocean, the lowest value in the data set is 860, giving a range of only 152 for this parameter. The range in values decreases significantly with depth. High values of the parameter, suggesting the injection of excess CO2 are found at stations in the North Atlantic (Station 32), The Southern Ocean (Stations 76, 280, 430, 432) and in the SW Pacific (Station 303).

The higher values near the surface, however, only exceed near bottom values by about 30 micromoles/kg. The index as here defined ignores nutrient cycling which affects both the alkalinity and the dissolved oxygen concentration. Since the nutrient concentrations undergo variations of similar magnitude, the index will have to be refined before it can be used to study changes in the storage of CO2 in the ocean.

So far, only selected stations have been processed. To complete the inventory, the rest of the GEOSECS data must be processed. To assign volumes to the T-S classes, the GEOSECS data set must be supplemented by other hydrographic data. The final product will give the volume for each T-S class by ocean area. This will give us a quantitative estimate of the chemical contents of the world ocean. In addition, the information set can be used to develop dynamic models in T-S space. These consider the change in the ocean content in response to assumed processes of water formation, upwelling and mixing.

The information system, by providing a broad overview of the chemistry of the world ocean will enable us to discern important appropriate questions and, in environmental research, that is a major step towards obtaining answers. The system should find wide application in instruction in descriptive oceanography and in research.

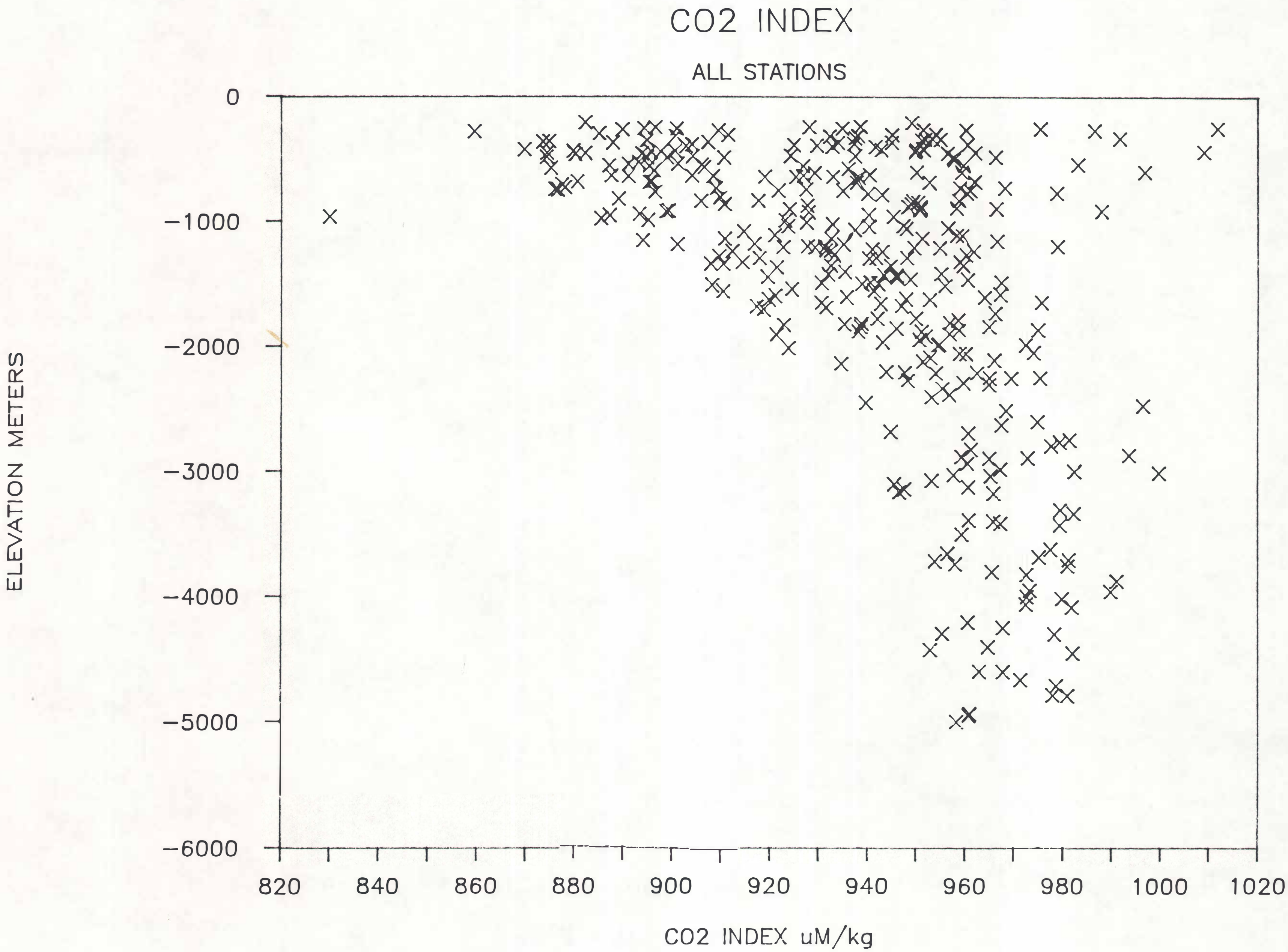

CO2 INDEX
ALL STATIONS
0
−1000
−2000
−3000
−4000
−5000
−6000
ELEVATION METERS
820
840
860
880
900
920
940
960
980
1000
1020
CO2 INDEX uM/kg

Figure 1.

4. The Surface Ocean Information System

The surface ocean, here defined as the upper 200 meters presents a more formidable problem, since time variations are important. Not only must one deal with seasonal changes, it is the deviations from average seasonal behavior that must be explored to improve our understanding of short term climatic change.

As an initial effort, I have developed indices of the thermal inertia of the sea surface, independent of atmospheric conditions. A draft paper, including results using the West Pacific Profile from the GEOSECS Expedition is appended. It demonstrates the large space-time variability of the sea surface.

A large variety of complex physical, chemical and biological processes take place in the surface layer of the ocean. To help us understand how these processes may lead to climatic change, it is necessary to examine oceanographic data in an iterative way. One starts with a hypothesis. This leads to an examination of average oceanographic parameters to locate the prime regions where the assumed mechanism is likely to be important. Next, one requires hydrographic data from the area. This is combined with quantitative information on the forces acting and their time variability, to develop worksheets that simulated the hypothetical process.

The task is difficult, however, the new tools of analysis are very powerful. The trick is to identify a few tractable problems and develop appropriate simulations that capture the essence of the processes. At worst, one will learn that the proposed mechanism can not be significant. Compared to observational programs, the costs are small. The benefits can lead to important new insights on how the ocean interacts with the atmosphere to produce our climate.

REFERENCES

Fuglister, F. C. 1960; Atlantic Ocean Atlas from the International Geophysical Year; Woods Hole Oceanographic Institution.

Montgomery, R. B. 1958; Water Characteristics of Atlantic Ocean and of world ocean; Deep Sea Research v.5, pp.134-148.

Weyl, Peter K. 1968; The Role of the Ocean in Climatic Change: A Theory of the Ice Ages; Meteorological Monographs v.8, pp.37-62.

DUE DATE

			Printed in USA