Geophysical Monitoring for Climatic Change

No. 2

Summary Report 1973

U.S. DEPARTMENT
OF COMMERCE

NATIONAL
OCEANIC AND
ATMOSPHERIC
ADMINISTRATION

ENVIRONMENTAL
RESEARCH
LABORATORIES

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE NO. 2 SUMMARY REPORT - 1973

John M. Miller, Editor

DISCLAIMER

The NOAA Environmental Research Laboratories do
not approve, recommend, or endorse any proprietary
product or proprietary material mentioned in this
publication. No reference shall be made to the
NOAA Environmental Research Laboratories, or to
this publication furnished by the NOAA Environ-
mental Research Laboratories, in any advertising
or sales promotion which would indicate or imply
that the NOAA Environmental Research Laboratories
approve, recommend, or endorse any proprietary
product or proprietary material mentioned herein,
or which has as its purpose an intent to cause
directly or indirectly the advertised product to
be used or purchased because of this NOAA Environ-
mental Research Laboratories publication.

<div align="center">CONTENTS</div>

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE
NO. 2
SUMMARY REPORT - 1973

1. SUMMARY

The Geophysical Monitoring for Climatic Change (GMCC) program objectives remain the same: collection of accurate observations of atmospheric trace constituents, maintenance of data quality, presentation of these data for interpretation by the scientific community and by GMCC staff.

During 1973, there was the beginnings of a shift from the previous emphasis on establishing observatories, which had consumed most of the effort and resources, to developing uniform operating and reporting procedures. The amount of data has increased and this has led to the design of centralized data handling methods to cope with the flood of information expected in 1974 and 1975.

The major physical changes within the observatory network occurred with the completion of the total ozone observational dome at Point Barrow (Dobson spectrophotometer facilities), the preparatory design work for major additions to the South Pole program during the 1973-74 austral summer, and the construction of a sampling tower at Samoa for the cooperative National Oceanic and Atmospheric Administration (NOAA) — National Center for Atmospheric Research (NCAR) program.

The programs at the several observatories were augmented to include an increase in more sensitive aerosol data, surface ozone instrumentation, sampling for freon (CCl_3F) and carbon tetrachloride (CCl_4), and inauguration of precipitation collection for chemical analyses at Mauna Loa, Samoa, and Point Barrow. The largest advance was at Point Barrow where the program increased by orders of magnitude with the start of continuous observations of Aitken nuclei, surface ozone, carbon dioxide, and a schedule of total ozone determinations. The detailed schedule is discussed in section 3.3.

The measurement program and the data output increased markedly with the activation of observatories other than Mauna Loa. Considerable effort went into improving the total ozone network at the observatories and at locations in the contiguous U.S. including the National Weather Service (NWS) Stations. This reflects the increasing emphasis on the importance of accurately measuring the global characteristics of ozone. These data were complemented by the inauguration of surface ozone data at all of our observatories. These measurements are already beginning to indicate an annual cycle in surface ozone, but phase relations differ at each observatory. Data taken at the sites (see sec. 4.1.3) show very little diurnal variability in contrast to the strong cyclic behavior in urban areas. We have also assembled South Pole surface ozone data from 1960 on. These data show the strong annual cycle and, importantly, the need for careful intercomparison and calibration of instrument systems. Typical surface ozone values range from near 2 pphm (parts per hundred million by volume) at the South Pole, 1 to 3 pphm at Barrow, and 2 to 3 pphm at Mauna Loa.

In September 1973, flask sampling for CCl_3F and CCl_4 began. The technique used evacuated flasks and has not been completely satisfactory because of periodic flask contamination during the sample procedure. Since concentration levels are of order $70-100 \times 10^{-12}$ part per part, great care is required to insure representative data. A new positive pressure sampling system is being developed.

The test and development of the lidar system at Mauna Loa continued with a modest data collection program. Signal automation will be accomplished in 1974, permitting more scheduled observations. Lidar systems are planned for all observatories.

Routine collection of Aitken data continued, and automatic systems were installed at Mauna Loa, Barrow, and the South Pole. However, the bulk of the data is still from the manual Gardner counters. Clean air values at Barrow are below 350 n/cc, but occasional flow from the Naval Arctic Research Laboratory and Barrow village areas causes levels to reach above 10000 n/cc. In Samoa, values are lower, near 250 to 300 n/cc, and 99 percent of the observations there are less than 400 n/cc. The Aitken data at Mauna Loa reflect the diurnal wind regime; the values in the downslope flow are near to or less than 300 n/cc and rise to more than 1000 n/cc in the afternoon up-slope flow. South Pole values are below the 200 n/cc threshold of the Gardner counter unless affected by camp effluent. The more sensitive Pollak counter will be operated at South Pole during 1974 in a cooperative program with the State University of New York, at Albany.

The solar radiation monitoring program was much augmented with the delivery of most of the multi-channel systems, the receipt of several "absolute" pyrheliometers, and a double beam recording spectrophotometer to use in calibration work. In addition, computer programs for processing the voluminous magnetic tape solar radiation data were developed.

A special program for measuring solar ultra-violet radiation intensity over a spectrum that matched the human skin response was initiated. This project required the design and construction (by Mr. W. Komhyr) of unique radiation dosimeter instruments. The purpose of the program was to develop and test calculational models of this erythema spectrum given total solar radiation intensity, turbidity, total ozone, and weather conditions. In June one of these instruments was deployed at Bismarck, North Dakota, and another at Tallahassee, Florida.

Early in the design of the Geophysical Monitoring for Climatic Change program we decided that the volume of data generated by the extensive sampling programs required data automation using a small on-site computer system. The need for uniform sampling, data entry, and averaging procedures could also be met most economically by automation. The design and construction of the first system together with the necessary programming (software) was completed in time for installation at the South Pole Observatory at the end of the year.

The year saw Geophysical Monitoring for Climatic Change staff assigned to three new observatories, the acquisition and installation of significant new measurement programs, and the establishment of initial support facilities and staff for data quality control and processing and for analyses.

2. OBSERVATORY FACILITIES

This section describes additions and changes made in the physical facilities of the observatories with special attention given to construction or relocation of an observing systems that are relevant to the character and quality of the measurements. These changes are described for each observatory.

2.1 Mauna Loa

During 1973, there were three major improvements to MLO facilities: (fig. 1)

1. The inadequate electrical system at the observatory was completely rewired. This project included a new 200 ampere service entrance, the addition of the AEC building to the NOAA monitoring network, and the conversion of many receptacles to three-wire grounding types. Substantial improvements were made to the grounding systems to reduce the likelihood of lightning damage.
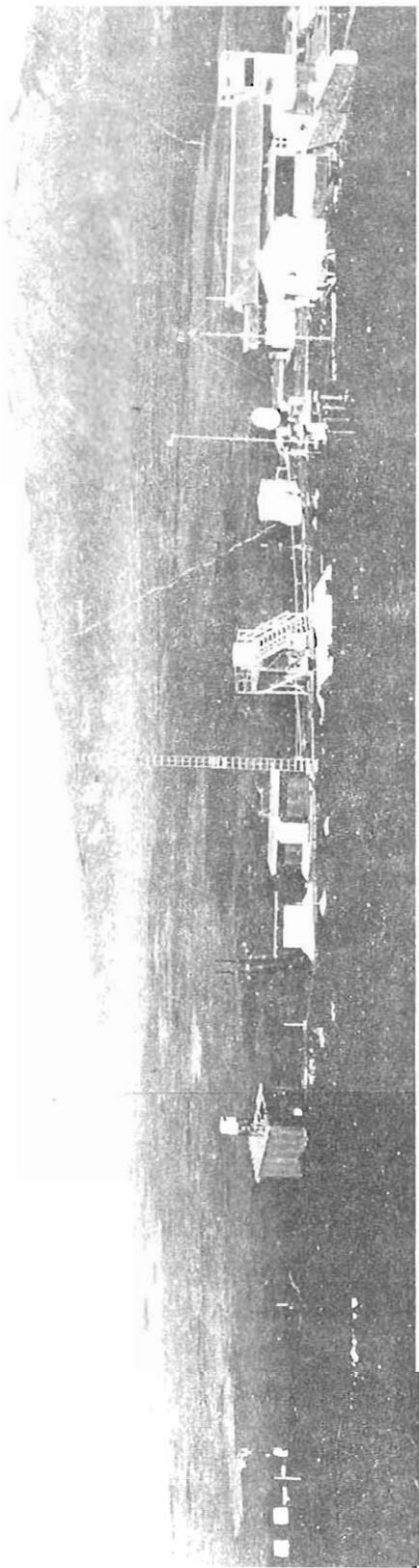
Figure 1. Mauna Loa Observatory facilities.

2. The construction of 3 meter high platform was completed for the AEC aerosol sampler.

3. Because traffic to the observatory had become a problem, a chain was placed across the road. This barrier stops the flow of traffic 14 km from the observatory.

2.2 South Pole

Total ozone, surface ozone, and condensation nuclei were measured at South Pole Station (fig. 2) during 1972-1973 by the winter-over observer, Mr. Russel Wertz. In late November 1972, the Dobson building, from which all measurements were made, was moved from its location near the balloon inflation tower to approximately 100 feet grid north of the cosmic radiation building. Air contamination from the then functioning Rodriguez well necessitated this move.
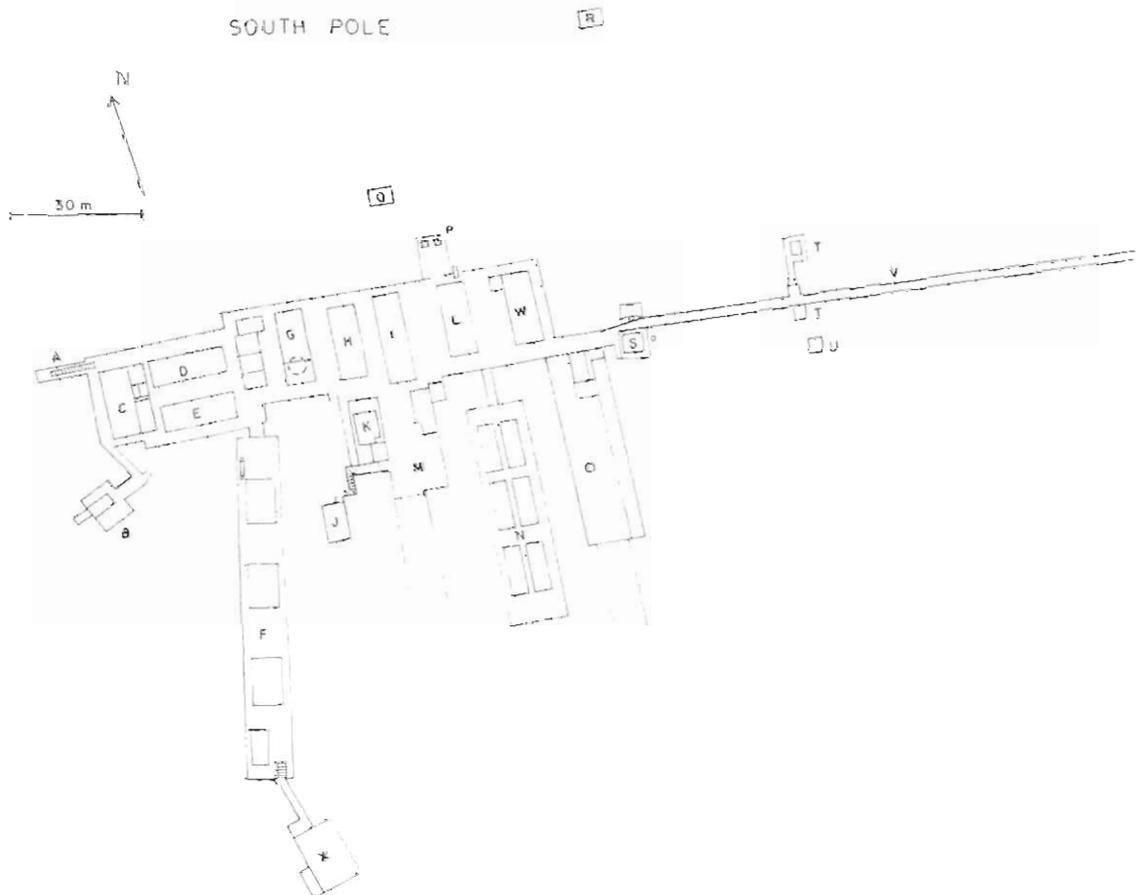
Figure 2.   Site sketch of South Pole Station.

	Location Code
"Holy Stairs"	A
Emergency generator	B
Sick bay	D
"Taj Mahal"	E
Fuel cache No. 1	F
Galley and weather station	G
"Club 90"	H
Builder's shop	I
Generator shack	J
Recreation room	K
Barrack	L
Builder's tunnel	M
Fuel Cache No. 2	∷
Supply	O
Snow melters	P
Communications	C
Aurora Tower	Q
Cosmic radiation	R
Inflation shelter	S
UCLA gravity meter	T
Dobson spectrophotometer hut	U
Seismology tunnel	V
Science building	W
Garage	X

2.3 Barrow, Alaska

The Barrow Observatory began operations with the arrival of Mr. Dan
Williamson on January 15, 1973. The main laboratory, road, and power
lines had been completed by the end of 1972. The installation of scien-
tific equipment continued throughout the year. A vehicle was purchased
and used for transportation to the site. Personnel housing was provided
by Naval Arctic Research Laboratories and support services by the Office
of Naval Research.

During the summer, a Dobson platform, a tower base and a 17-meter
sampling tower were constructed. An Ash astronomical dome was assembled
on the Dobson platform and spectrophotometer No. 76 was installed. The
dome is insulated, wired for electricity, and temperature controlled. In
addition to these separate structures, the main laboratory building has
a flat 7.3 x 6.1 meter platform on the roof for various external sampling
systems. The laboratory has 110-220 V service and is electrically heated.
Figure 3 shows the observatory building and tower.
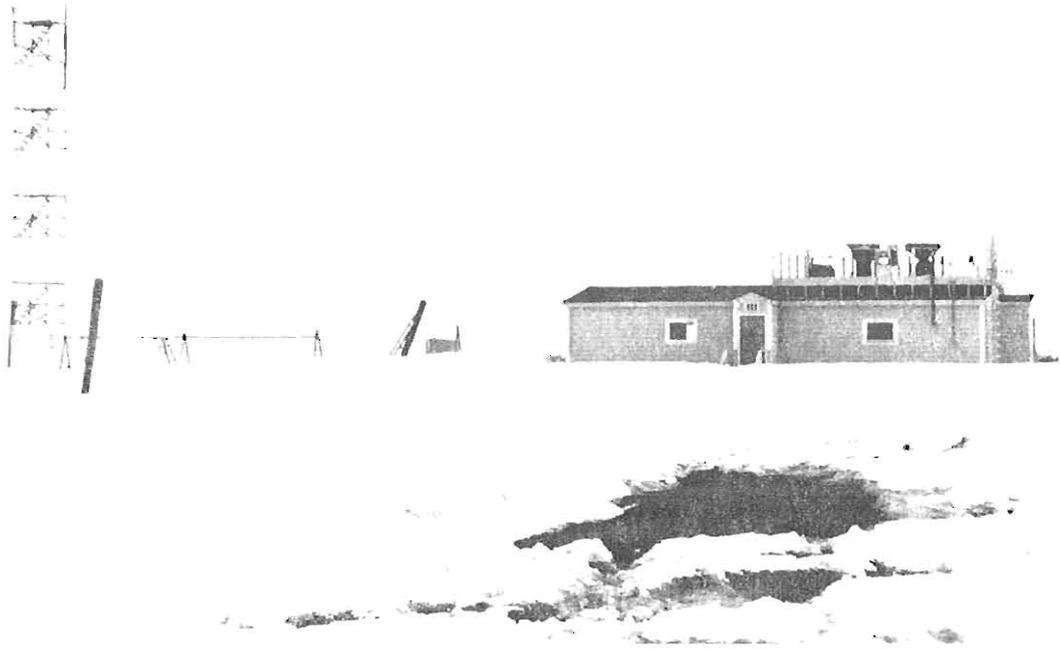
Figure 3. Observatory building and tower at Barrow.

The access road to the observatory was inadequate for wheeled transportation during the first summer's operations. Contracted maintainance was unable to keep the road serviceable. Throughout the year, the road represented the major obstacle to consistent and proper observatory access, and therefore the major area of concern. Figures 4 and 5 describe the site and its position relative to surrounding landmarks.

2.4 Samoa

On June 10, 1973, Vern Rumble, first GMCC station chief, arrived in American Samoa. A trail was blazed, with the aid of Tula villagers, through the jungle to obtain access to the Cape (fig. 6). In late June, meteorological measurements and air sampling were initiated. A 10 meter sampling tower was constructed and erected in October atop Lauagae Ridge, highest knoll of the Cape, as part of a program (sponsored by the National Center for Atmospheric Research) to measure trace atmospheric gases.

Measurements have been made at Matatula Point and Lauagae Ridge (fig. 6). Data taken from July through December show winds on Matatula Point to be quite strong and constant, with an average speed of 7.4 m/sec from east-southeast quadrant more than 70 percent of the time. Due to the closeness of the ocean (below or horizontal), relative humidity on the

7

Figure 4. Barrow, Alaska, GMCC observatory site.
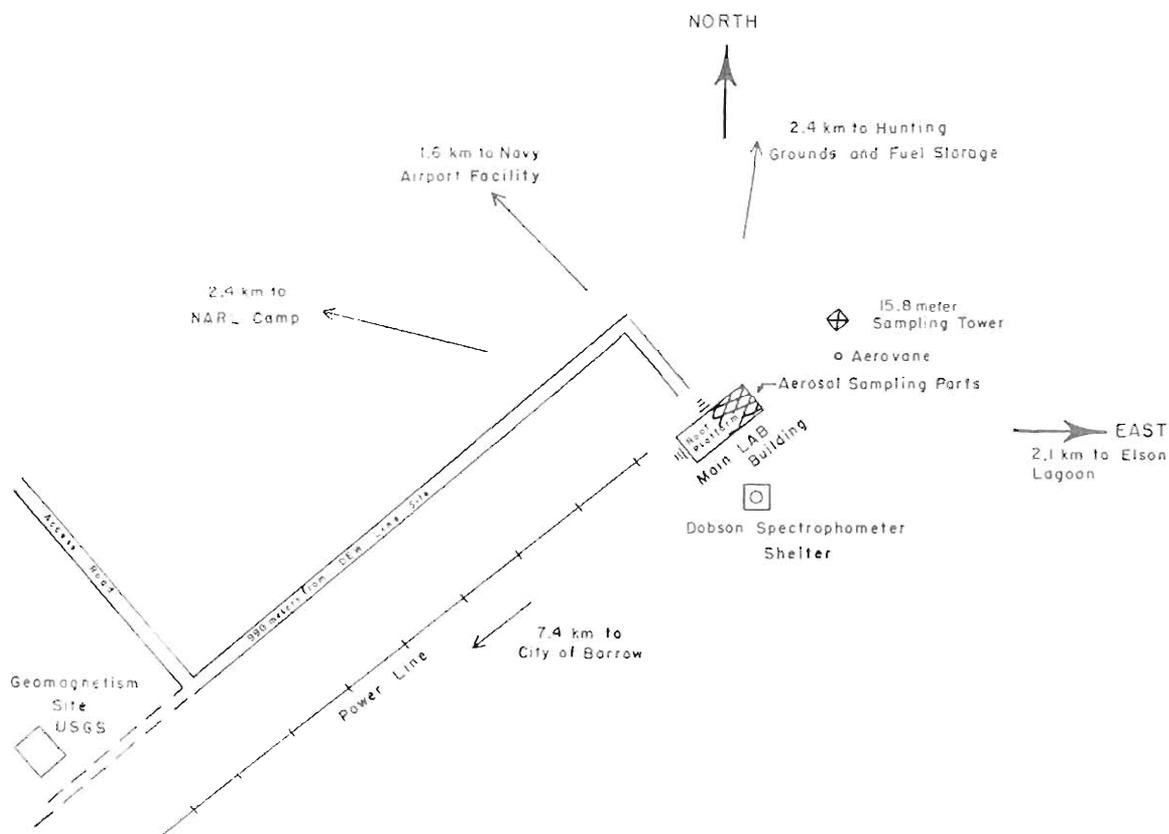
Figure 5. Orientation of Barrow observatory.

Point averages over 90 percent, and salt spray becomes visible on the ridge at wind speeds > 9 m/sec. This corrosive environment will be considered when permanent sampling equipment is installed on the point. Condensation nuclei readings obtained from the point range from 250 to 400 n/cc, at the lower threshold of the Gardner counter, attesting to the cleanness of the easterly trades. Condensation nuclei readings taken from Lauagae Ridge, planned location of the observatory building, appear equally as low as on the Point. However, wind speed on the ridge averages only about 2 m/sec, and air temperature runs a few degrees higher than on the point.

Design details of the observatory are being formulated by NWS Pacific Region Headquarters, Honolulu. Construction of the building will tentatively begin in August 1974 and should last about 8 months. Improvement of the access road and erection of a power line will be completed before construction begins. Electrical power for the eastern district is supplied by the Satala power plant at Pago Pago harbor. The station's water supply will be maintained by catching rain in a 38 kℓ tank. The 27 x 5 m building will be longitudinally oriented north and south (fig. 7).

9
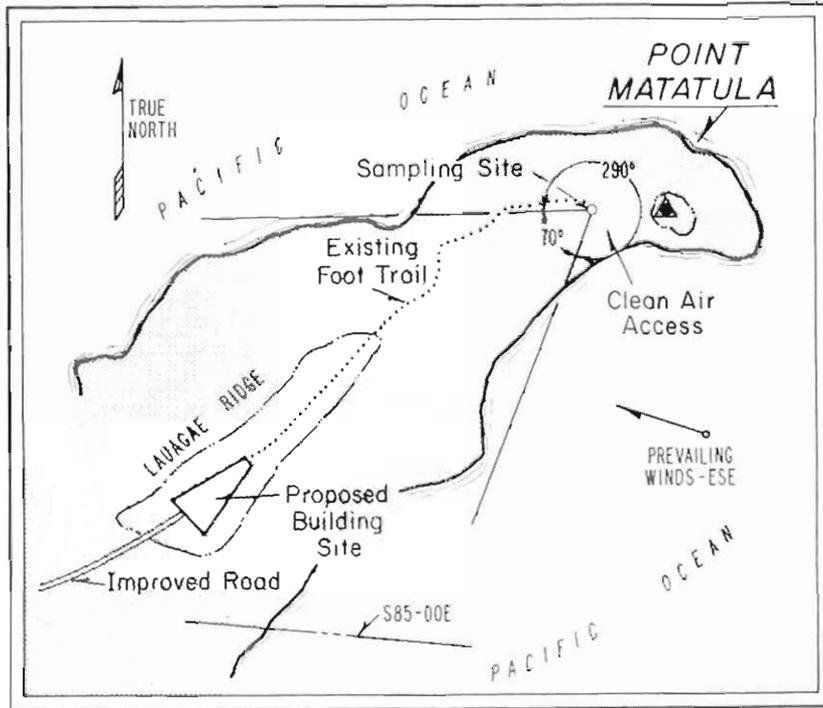
Figure 6. Cape Matatula on Tutuila
Island American Samoa.

All measurements made so far indicate that Cape Matatula is indeed an excellent location for sampling very clean sea air. The establishment of a GMCC program in Samoa could not have been possible without local acceptance and support. Considerable recognition and thanks are due to High Chief Iuli, his Aiga, and the Government of America Samoa.
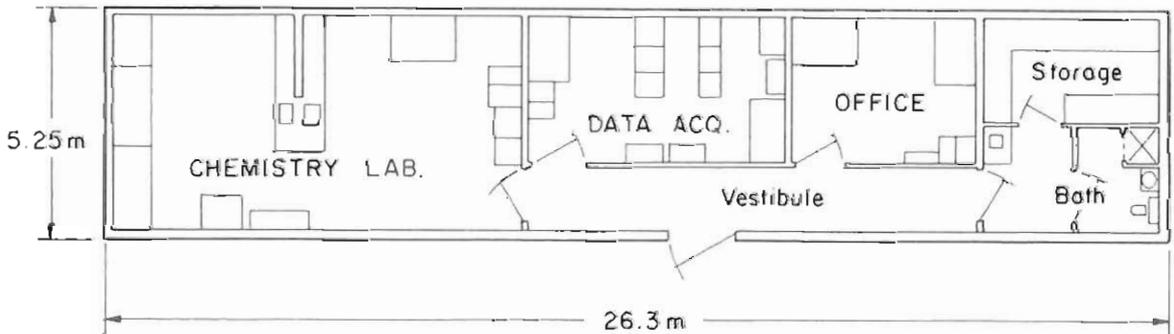
Figure 7. Samoa Geophysical Monitoring Observatory preliminary
floor plan 138 m².

2.5 Planned Stations

Besides the four established observatories two more are planned near the eastern and western boundaries of the United States. These stations will perform the same functions as the others and likewise be located in areas where there is access to locally uncontaminated air. In combination, these stations will afford a unique examination of transport, dispersion, and removal processes of pollutants originating from a major industrialized area, viz., the U.S. Combined with intensive measurements within the United States itself, a great deal of knowledge can be obtained from the "clean" air that enters the U.S. via the westerlies, and that which leaves the U.S. off the eastern coast.

Potentially favorable locations for these two new sites have been suggested as the west coast of the U.S. and in Bermuda. The placing of these two observatories is much more difficult than the past four. The dichotomous sampling needs for the various parameters and the rapid development of land areas in the U.S. make it necessary to study the future sites with preliminary and mobile sampling programs and to understand fully the growth potential and meteorology of each site.

Preliminary sampling and meteorological studies have started in both areas. For several months, Aitken particle counts and CO_2 flask samples were made for us by the University of Rhode Island at High Point, Bermuda. Aerosol filter sampling are also being done by the University at this site. On the west coast, a survey of land use, topography, and meteorology indicated that the site should be located on the coast somewhere between Northern California and northern Washington. A trip was made to inspect the most likely locations on which to base more intensive studies and measurements. The University of Washington and Washington State University agreed to study this under contract to GMCC. Continued efforts are being made in planning these additional two observatories.

3. OBSERVATORY PROGRAMS

This section is a brief summary of operating programs and, where relevant, a description of both problems and solutions, the instrument systems used are emphasized.

3.1 Mauna Loa

The year 1973 was one of program initiation and improvement at MLO. Several new measurement programs were begun, and the quality control of all programs was improved. The following are some of the new programs and changes made in ongoing programs:

1. The continuous measurement of surface Aitken nuclei concentration by a General Electric counter.

2. A four-wavelength nephelometer for measuring the optical properties of surface aerosols.

3. Continuous surface CO concentration measurements.

4. Periodic lasar radar detection of in the height and reflective strength of tropospheric and stratospheric aerosol layers.

5. Continuous surface ozone measurements.

6. Periodic measurements of several atmospheric gases using the new NCAR air chemistry system.

7. Periodic flask samples for atmospheric. CCl_3F and CCl_4 analysis.

8. Chemical analysis of precipitation.

9. A High Altitude Observatory IR hygrometer for measuring the total precipitable water.

10. The CO_2 system was put back into operation at year end after experiencing a period of intermittent difficulties during September and November.

3.2 South Pole

In general, the Dobson spectrophotometer, the ECC oxidant meter, and the Gardner counter performed well throughout the 1972-1973 Antarctic season.

Dobson Spectrophotometer — Serial No. 80: Separation in the mercury column occurred because the thermometer was exposed to extreme cold and the mercury froze. Thermometers with separated mercury columns were periodically replaced with new ones.

ECC Oxidant Meter — Serial No. 002: There were several failures of the meter's solution pump, always caused by rupture of the pump tubing. One failure was attributed to normal material fatigue and the others to the effects of the solution freezing inside the pump when a door or window was inadvertantly left open.

Periodic, large and abrupt decreases in the measured ozone amount with a very slow recovery to levels measured prior to the decrease indicate a possible contamination of the solution flow system and make the data gathered during the year of questionable quality.

Gardner Counter — Serial No. 1126: In general, the readings during 1972-1973 were at the threshold of sensitivity of the instrument. Any

12

local contamination of the air samples was obvious in that the readings would be several orders of magnitude higher. Only normal periodic main-tainance was required. (Measurements made in the Aurora tower with a precision Pollak counter operated for the State University of New York gave Aitken nuclei counts of < 100 n/cc from the clean air direction. This demonstrates the need for super-sensitive devices.)

3.3 Barrow

The programs listed in table 1 are those in operation by the end of 1973.

Two long term cooperative programs were conducted: the Smithsonian Radiation Biology Laboratory's pyranometer system with clock and paper tape print-out, and the operation of a Hi-Vol sampler for Dr. Fritz Wendt of Desert Research Institute, University of Nevada. Both programs are located on the roof of the observatory.

3.4 American Samoa

Appraisal of several Pacific islands led to the selection of the is-land of Tutuila of American Samoa as an excellent possibility for a South-ern Hemisphere baseline station. Two preliminary expeditions, one in April 1972, and another in September 1972, were made to Samoa to take Ait-ken measurements and CO_2 flask samples to determine if Cape Matatula had clean air and suitable background conditions. Both expeditions indicated this to be true, and land negotiations began with local land owners. A preliminary program was then planned to send GMCC observers to the island to conduct an initial program to yield CO_2, surface ozone, meteorological, Aitken nuclei, turbidity, and precipitation data, and to operate the six component NCAR system. At the end of this trial period whether to build a permanent observatory and add other component systems would be decided.

Meteorological measurements and air sampling began in June 1973 shortly after the arrival of Vern Rumble, first GMCC station chief. All instruments had to be portable, battery powered models, because no power was available on Cape Matatula. Experience gained in the operation of equipment in such a hot, humid environment will be invaluable later in the design and selection of more sophisticated systems.

It became obvious towards the end of 1973 that Cape Matatula was in fact a prime location for baseline measurements as a conjugate station to Mauna Loa. In November, a long-term lease was signed with the local prop-erty owner, Chief Iuli, and plans for the construction of the observatory were formulated. Table 2 lists chronologically the programs and equip-ment operating in American Samoa.

13

Table 1. *Summary of Barrow Operations*

System	Date of Installation	Down Date	Problems	Operation Time (%)
Gardner Aitken Counter	Before 1-1-73	3-30 to 4-05	No Batteries	98
Surface Ozone ECC Meter Model 002	3-14-73	None	None	100
Temperature & Dew Point Hygrometer	2-18-73	None	Increased Maint. during winter	100
GE CNC	5-18-73	9-21 to end of year	Gear failure & optical problems	60
CO_2 Flask Sampling	Before 1-1-73	None	None	100
Mercurial Barometer	5-20-73	None	None	100
Wind direction & speed	2-17-73	None	None	100
Sunphotometer DA-49 (#4630 secondary/standard)	3-02-73	None	None	100
Precipitation Chemistry Collector	9-1-73	11-1 to end of year	Too cold for instrument	50
Dobson Ozone Spectrophotometer	8-1-73	None	None	100
UNOR CO_2 Continuous NDIR Analyzer	8-1-73	8-7-73 (3 hours)	Failed solenoid power supply	100
Cloud Cover Observations	Before 1-1-73	None	None	100
Freon-11 Flask Sampling	9-20-73	None	None	100

Table 2. Programs at American Samoa.

Parameter Measured	Observations Initiated		Instrument	Responsible Agency
Air Temperature	06-20-73	1)	Belfort hygrothermograph, vertical drum type, cont. operation	GMCC
		2)	MRI mechanical weather station, cont. oper.	
Wind speed and direction	06-20-73		MRI mechanical weather station, cont. oper.	GMCC
Rainfall	06-20-73	1)	8" rainfall collector	GMCC
		2)	MRI tipping bucket, continuous operation	GMCC
Humidity	06-20-73		Belfort hygrothermograph, cont. oper.	GMCC
CN/Aitken nuclei	06-20-73		Gardner small particle detector model CN	GMCC
CO_2 concentration	07-02-73		½ liter flasks	GMCC
Atmospheric Turbidity	08-07-73		Eppley Sunphotometer Model DA, 380 & 500NM	WMO,EPA
Rain Chemistry	08-09-73		Microchemical specialities, precip collector, model 93	EPA
Dew point	08-14-73		Sling psychrometer	GMCC
Freon-11 Concentration	09-25-73		Stainless Steel Flasks	GMCC
SO_2, NO, NO_2, NH_3, H_2S trace levels	10-03-73		NCAR multigas analyzer & mechanical weather station	NCAR

15

4. MEASUREMENT PROGRAMS

This section serves two purposes: first to describe information systems qualitatively and quantitatively, and second, to present representative data samples collected and/or summarized during this period. Because this latter function will continue to increase, the next annual summary will include a new section "Data Reports."

An overview of the complete GMCC program's performed during 1973 is given in appendix A. As a complement to appendix A, appendix B has a list of the master manuals file for those measurements that have instruction manuals provided.

4.1 Gases

4.1.1 Carbon Dioxide

The CO_2 program, using the Applied Physics Co. infrared analyzer, continued at MLO during 1973 in the same manner as described in the GMCC Summary Report 1972.

In July of 1973, an UNOR infrared CO_2 analyzer began operation at Barrow. The analyzer system, including H_2O freeze-out unit and reference gas tanks, is shown in figure 8.

The 1973 MLO and Barrow CO_2 data are tabulated in table 3, and plotted in figure 9. In light of the recent discovery that different kinds of CO_2 analyzers respond differently to ambient air CO_2 concentrations when using CO_2- in-N_2 reference gases, the Barrow data have been made compatible with the MLO data by subtracting 5.0 ppm from all CO_2 values derived by the UNOR analer. The appropriate adjustment value to use to achieve data compatability was tentatively deduced from laboratory
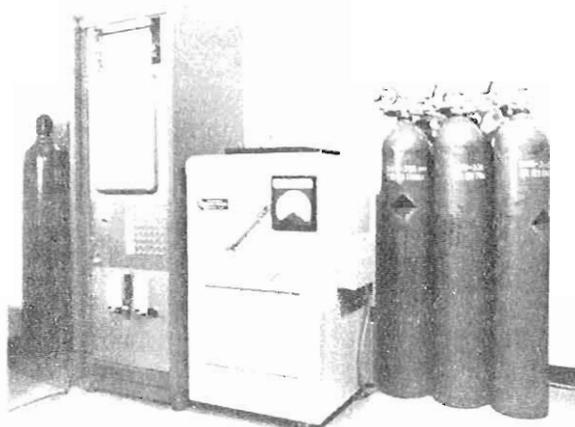
Figure 8. CO_2 analyzer system- Barrow.

16

Table 3. Mean Monthly CO₂ Concentrations

1973	Barrow, Alaska			MLO, Hawaii*		
January				322.53 ppm	("index")	
February				323.17	"	"
March				323.99	"	"
April				324.66	"	"
May				325.54	"	"
June				325.30	"	"
July				323.97	"	"
August	317.89 ppm	("index")		322.70	"	"
September	320.45	"	"	321.43	"	"
October	323.65	"	"	321.45	"	"
November	326.81	"	"	322.09	"	"
December	326.94	"	"	322.53	"	"

*From Scripps Applied Physics analyzer.
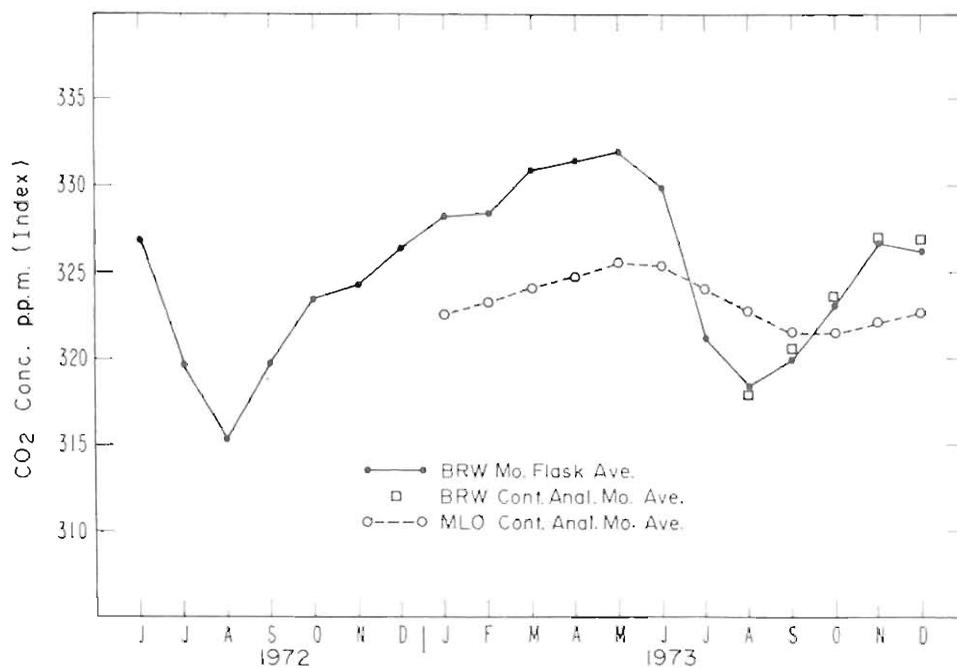
Figure 9. CO₂ "index" values at Mauna Loa and Barrow for 1972-1973. Final concentration values determined after re-checking calibration gases.

investigations in Boulder, Colorado, as well as from an analysis of continuous analyzer and CO_2 flask data obtained simultaneously at Barrow.

During early 1974, we plan to establish a new CO_2 analyzer measurement system at MLO employing a URAS 2 infrared analyzer. The new system will replace the one currently in use after sufficient data overlap for the two systems has been obtained. In late 1974, also, we plan to begin operations at South Pole, Antarctica, with an UNOR 2 CO_2 analyzer.

The plots of figure 9 clearly reveal the large difference in the amplitude of the CO_2 annual cycle at Barrow and MLO. A cursory examination of changes in CO_2 concentrations was made of the August 1973 Barrow data, the time of the year when such changes are largest. The data were compared with John Kelley's 1965 results obtained at North Meadow Lake near Barrow. For August of both years, the amplitude of the diurnal change was essentially the same, i.e., about 1.5 ppm (1.4 ppm in 1973 and 1.5 ppm in 1965). Peak values occurred during the same hour 1400 GMT (0400 AST) in both cases.

The determination of carbon dioxide concentrations in the atmosphere by discrete sampling, i.e., flask pairs, continued into 1973 at the following locations: Barrow, Alaska; Cape Matatula, American Samoa; Ocean Station "Charlie," N. Atlantic; Key Biscayne, FL; and Niwot Ridge, CO. A new sampling program was begun at High Point in Bermuda in June 1973, but was discontinued in December 1973, when all other programs were curtailed at the site. Observations at High Point are expected to be resumed in 1974.

The 1973 Barrow, Bermuda, Cape Matatula, and Ocean Station "Charlie" CO_2 data are summarized in table 4. Included in the table are 1972 data for Barrow and station "Charlie" that were not published in the 1972 GMCC Summary Report. In all instances, CO_2 concentrations are expressed in parts per million index values referred to in the MLO CO_2 data baseline. Plots of the Bermuda, Cape Matatula, and Ocean Station "Charlie" flash data are provided in figure 10.

4.1.2 *Total Ozone* (O_3)

The year 1973 was productive for total ozone measurements and accomplishments. Not only were total ozone measurements continued at the 10 stations in the U.S. network, but two additional stations were established.

In June 1973, the Tallahassee, Florida, station that had operated from May 1964 to March 1970 was re-established at Florida State University. Then in July 1973 a new station was established at NOAA's Geophysical Monitoring for Climatic Change (GMCC) station at Barrow, Alaska. Table 5 is a complete list of the active stations in the U.S. network that measure total ozone.

18

Table 4. CO_2 Index Values Taken at Barrow, Bermuda, Samoa, and Station "Charlie" Collected by Flasks.

Year Month	Barrow 71°N. 156°W.			Bermuda 32°N. 64°W.			Samoa 14°S. 170°W.			Ocean Sta. "Charlie" 52°N. 35°W.		
	No. of Samples	Mean Conc. Index	σ	No. of Samples	Mean Conc. Index	σ	No. of Samples	Mean Conc. Index	σ	No. of Samples	Mean Conc. Index	σ
1972												
June	7	326.80	2.19									
July	10	319.72	1.18									
Aug.	8	315.28	0.91									
Sept.	7	319.66	2.47									
Oct.	7	323.37	2.34									
Nov.	5	324.21	1.91							2	322.76	0.47
Dec.	7	326.40	0.52							1	325.63	-
1973												
Jan.	9	328.17	1.41							8	327.14	1.14
Feb.	4	328.44	2.77							5	327.22	2.56
Mar.	5	330.93	1.50							7	327.60	1.07
Apr.	5	331.39	3.02							2	327.06	1.02
May	6	331.81	2.07							3	324.18	3.38
June	5	329.79	2.65	2	324.88	0.35	4	324.57	1.27			
July	7	321.08	3.80	2	320.88	0.64	6	324.68	0.89			
Aug.	6	318.40	0.96	6	324.33	0.61	2	323.66	0.29			
Sept.	8	319.87	1.45	5	322.01	1.47	4	324.16	0.32			
Oct.	3	323.01	0.17	5	323.63	0.75	7	323.80	0.33			
Nov.	4	326.56	1.55	4	325.75	0.49	2	326.02	0.99			
Dec.	2	326.20	0.76	2	324.41	0.24	9	324.68	0.74			

19
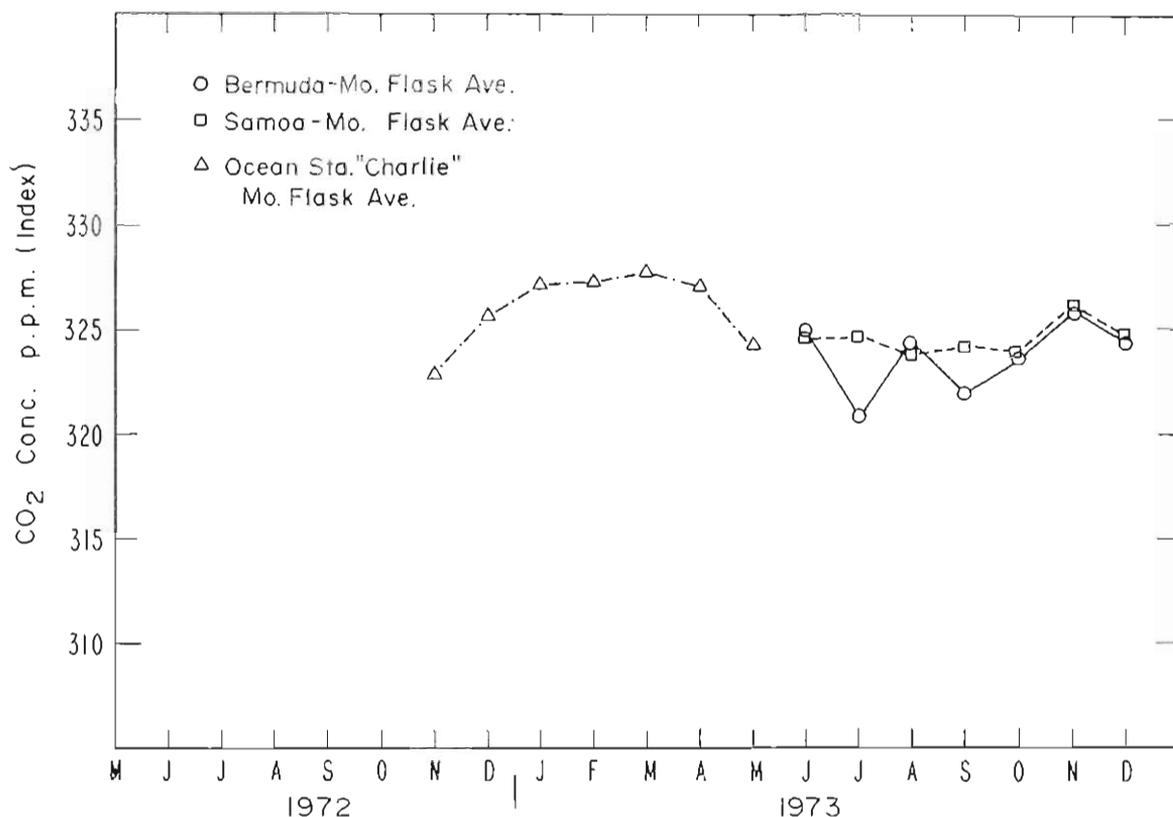
Figure 10. CO₂ index values at Bermuda, Samoa, and Station "Charlie."

New instrument shelters of the Ash Dome type (fig. 11) were erected at the Tallahassee, Florida; Caribou, Maine; Bismarck, North Dakota; and Barrow, Alaska, during the year. These new installations completed the program of upgrading the shelters at our total ozone observatories. With the exception of Huancayo, Peru, and Amundsen-Scott Station, Antarctica, all stations now use the Ash Dome type shelter.

In the past, there was some question about whether the Ash Dome structure would be satisfactory at Barrow, Alaska, and Caribou, Maine, where outside temperatures frequently drop lower than -40.0°C. All indications are that the domes are satisfactory, and that the 1 kW electric heaters furnished with the domes adequately maintain temperatures within the 15°C to 25°C range.

Modernization of Dobson Spectrophotometers. During the past 10 years, numerous difficulties have been experienced while operating the Dobson spectrophotometers. To overcome the difficulties, new calibration techniques have been devised, instrument optics improved, and the electronic and electromechanical systems of the instruments redesigned. The U.S. modified spectrophotometers now employ minature solid-state built-in high-voltage converters, modern solid-state amplifier circuitry,

20

Table 5. Dobson Ozone Spectrophotometer Stations

Station	Period	Ser. No.	Agency
Bismarck, N.D.	010163-Pres	33	NOAA-ARL
Caribou, Maine	010163-Pres	34	NOAA-ARL
Green Bay, Wisc.	010263-Pres	38	NOAA-ARL
Tallahassee, Fla.	060273-Pres	58	Fla. State U.
Mauna Loa, Hawaii	010264-Pres	63	NOAA-ARL
Wallops Island, Va.	070167-Pres	72	NOAA-ARL
Barrow, Alaska	080273-Pres	76	NOAA-ARL
Nashville, Tenn.	010163-Pres	79	NOAA-ARL
Amundsen-Scott	120563-Pres	80	NOAA-ARL
Boulder, Colo.	090166-Pres	82	NOAA-ARL
White Sands, N.M.	010572-Pres	86	Dept. Army
Huancayo, Peru	021464-Pres	87	NOAA-ARL

and electro-mechanical phase-sensitive rectifiers. Detailed information outlining the modifications have been described by Komhyr and Grass (1972).

The modification of the spectrophotometers has proved to be quite beneficial not only in their superior performance, but also because fewer days of data were lost due to instrument failure. Over the past 2 years, only four minor failures have occurred; they were readily and quickly corrected.

The Caribou, Maine; Tallahassee, Florida; and Nashville, Tennessee, Dobson Spectrophotometers were all modified during 1973. The only instruments in the U.S. network left to be modified are those at Green Bay, Wisconsin, and Huancayo, Peru.

Calibrations. Care must be taken to avoid possible long-term drifts in instrument calibrations. Since our initial 1971 analyses of North American total ozone data, which suggested that ozone increased during the 1960's, we have endeavored to recheck the calibration levels of our Dobson spectrophotometers to acertain whether instrument factors influenced the results.

To check the calibration of our reference Dobson spectrophotometer No. 83, the instrument was transported to Mauna Loa Observatory, Hawaii, in June 1972, for a special series of calibrations. The usual method of
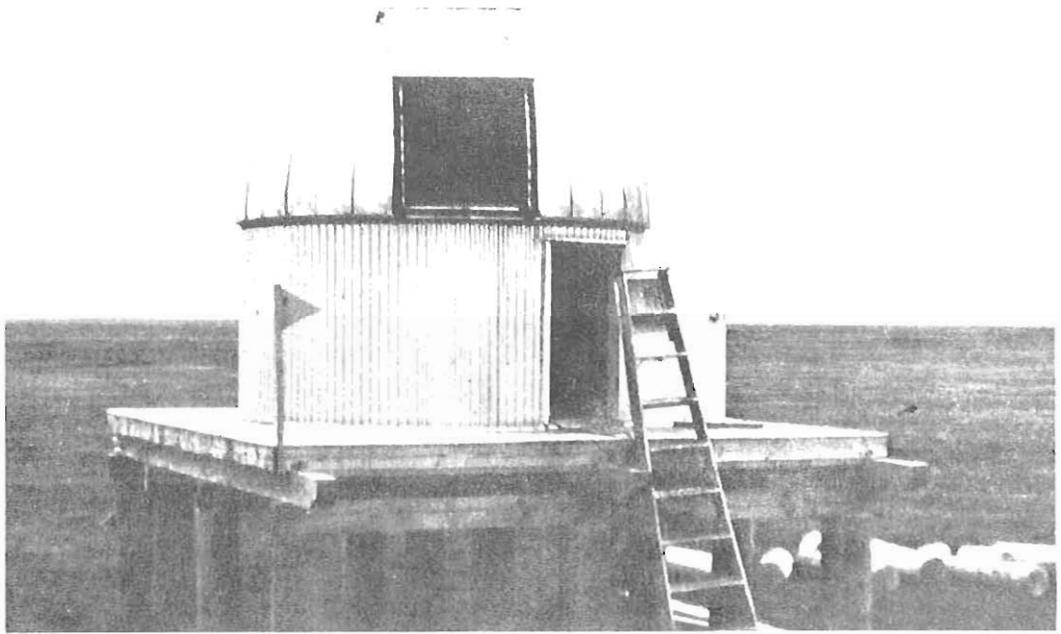
direct sun observations on A, C, and D wavelengths at various values of optical air mass was employed to calibrate the spectrophotometer. Only specially selected data, obtained on very clear half-days when the ozone amount was believed to remain nearly steady, were used. The calibrations revealed that the required correction to the reference spectrophotometer's $100N_{AD} = 100 (N_A-N_0)$ values, which are fundamental, was nearly zero, i.e., the instrument was virtually in perfect calibration. Required corrections to 100 N values for individual A, C, and D wavelength pairs were about 2.0 units. This result is not surprising; the instrument was originally calibrated near sea level at Sterling, Virginia, where even during the clearest days the air is not as clear as it is at Mauna Loa Observatory.

Within the past 3 years, all instruments in the U.S. network, except for the ones at Green Bay, Wisconsin, and Huancayo, Peru, have been recalled to Boulder, Colorado, for a direct comparison with the reference spectrophotometer. This involves making simultaneous direct sun observations with the two instruments on A, C, and D wavelengths for $1.0 < \mu < 3.5$.

The ideal situation would be to recheck the absolute calibration of all instruments each year, but this is logistically impossible. At the same time, whenever an instrument is recalled to Boulder for a calibration, from 2 to 4 weeks of data are lost because of its absence from the station.

Plans have been made to check the calibration of each spectrophotometer at least every 2 or 3 years. Rather than to recall the instruments to our central calibration facility in Boulder, we will visit the stations to perform the "two-lamp" wedge calibration on A, C, and D wavelengths. From a plot of the wedge calibration data, we can estimate the significance of any changes that might have occurred in the optical characteristics of the wedges. When changes are detected it will be necessary to recall the instrument to Boulder for a complete recalibration.

Data Summary. Figure 12 shows the monthly mean total ozone amounts, expressed in milli-atmo-cms, measured at the U.S. stations during 1973. The circled dots show the standard deviations associated with the monthly means, and represent the natural variability in the data as well as observer and instrument error. Data for the Amundsen-Scott, Antarctica, and Barrow, Alaska, stations have not been included because final corrections to the data have yet to be established.

4.1.3. *Surface Ozone*

During 1973, surface ozone was measured with Electrochemical Concentration Cell (ECC) oxidant meters (described in *GMCC Summary Report No. 1*) at Barrow, Alaska; Boulder, Colorado; Mauna Loa, Hawaii; and South Pole Station, Antarctica. A summary of the data obtained is included in this report together with information on the format and availability of the complete data set. The quality of the data and the effectiveness of quality control procedures used during the past year are also discussed briefly. Considerable progress was also made during 1973 in processing surface ozone data obtained in Antarctica during the 1960's. Some of these data are summarized in this report.

Data Summary. During 1973, surface ozone measurements commenced at the Barrow and Mauna Loa Observatories and continued at South Pole Station. Observations were also made in Boulder at the Techniques and Standards Group facility. The mean monthly ozone amounts for these four locations are shown in figure 13. The solid bars plotted with the mean show plus and minus one standard deviation from the monthly mean of the daily average surface ozone values. With the Boulder means, the standard deviation of the hourly values is also plotted and is represented by the solid and dashed portion of the bars. At the GMCC observatories, the variations within a day are quite small, thus the standard deviation based on daily averages and that based on hourly averages is almost the same. At Boulder, on the other hand, the large diurnal variation associated with human activity results in a significant difference between the two computations of the standard deviation.

The data taken at the South Pole during 1973 are of questionable quality. Comparison of the data taken in 1973 with that gathered during the past 10 years at the South Pole shows that the data from 1973 are

23
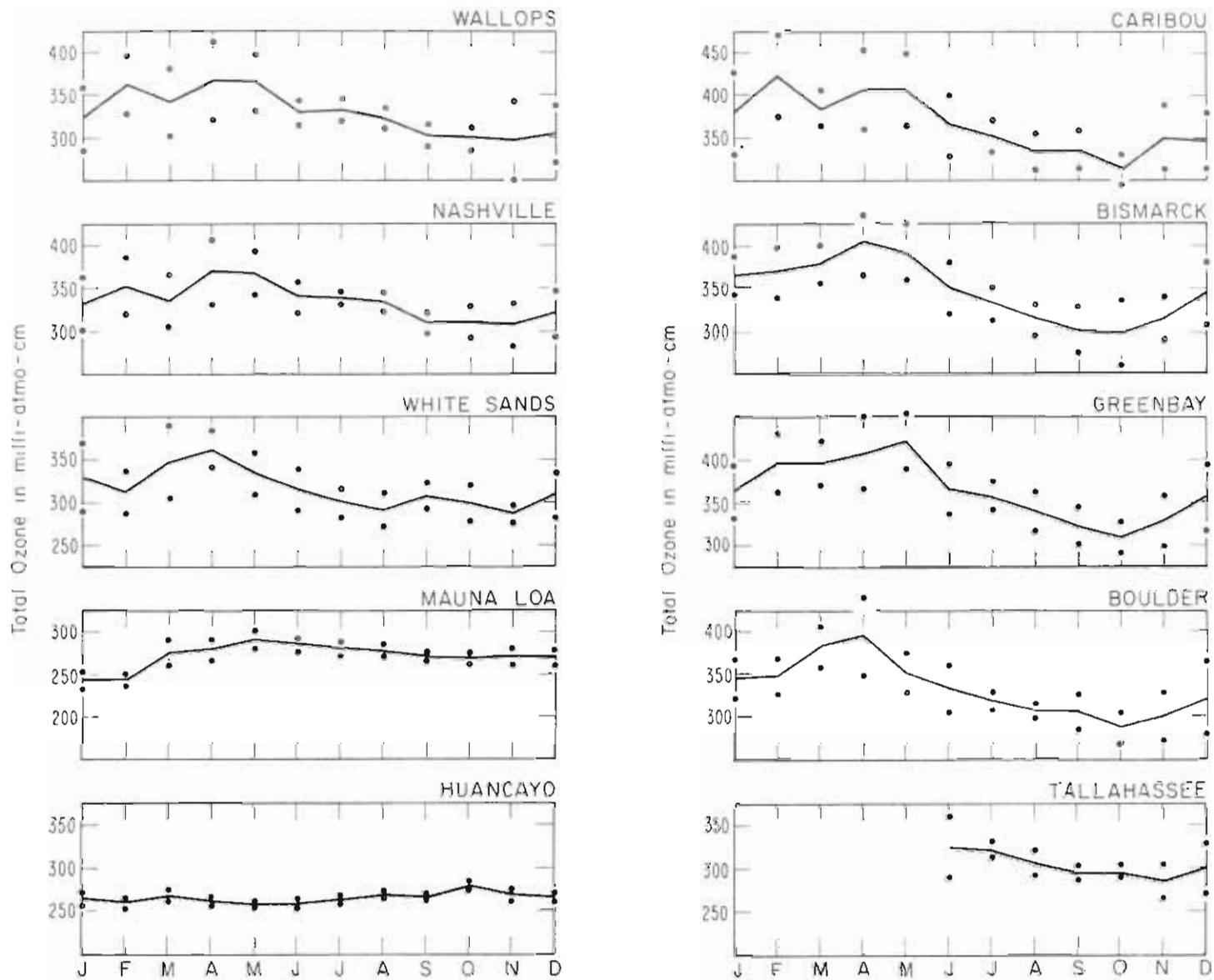
Figure 12. Total ozone at 10 stations for 1973.
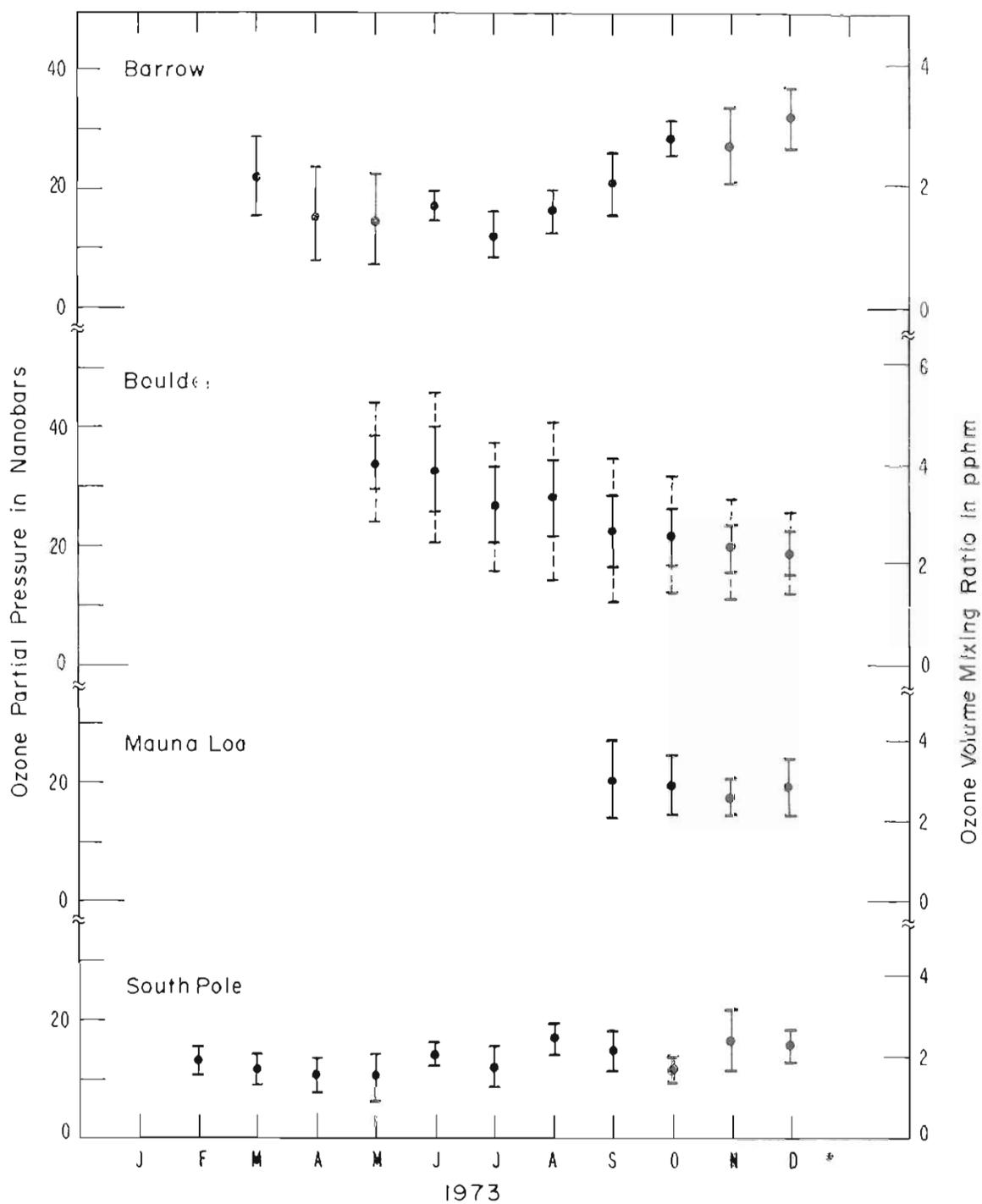
Figure 13. Mean monthly surface ozone. Bars represent plus and minus one standard deviation.

25

generally unrepresentative of ozone behavior at the South Pole. In particular, the 1973 data do not show the strong annual cycle that is a dominant feature of the previous data, and also they *under*-represent the maximum amount of zone measured by 25 to 50 percent. This deviation seems to stem from a problem that shows up in the record as a large, abrupt decrease in the recorded ozone amount followed by a very slow recovery to levels measured before the decrease. The sensing solution reservoir was probably contaminated, and the addition of solution to the reservoir may have stirred up the contaminants, which then required several days to be purged from the system.

Progress was also made in processing old data from the Antarctic. During the 1960's, measurements at the South Pole used four different types of instruments. The mean monthly values of the surface ozone partial pressure are summarized in figure 14. The most striking feature of this data is the strong annual cycle. There are also some year-to-year variations, although they do not appear to be of a regular nature. The data from the various instruments for the periods covered in the plot of figure 14 are available in the same format and form as described in the next section about the 1973 GMCC surface ozone network.
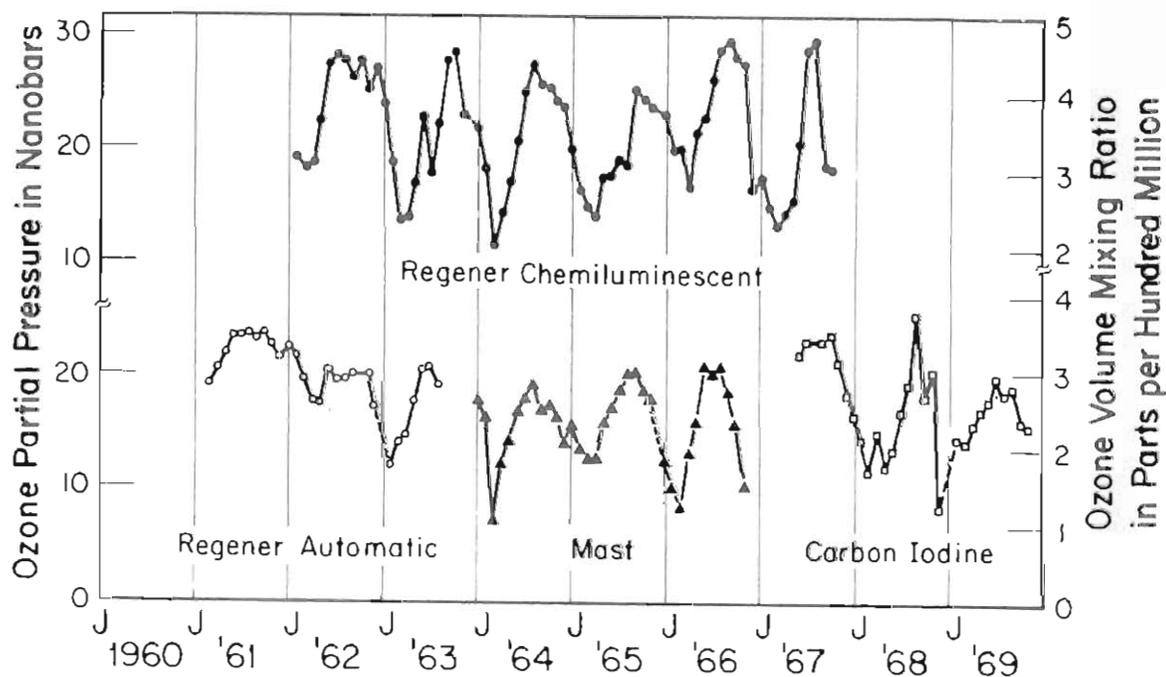
Figure 14. Mean monthly surface ozone at the South Pole.

Data Quality Control, Format, and Availability. Each of the Electrochemical Concentration Cell (ECC) oxidant meters was checked on a
monthly basis against a calibrated ozone source. This source had been
checked against the ECC meter with which it would be used before being
deployed to the field location. Through this procedure a check on the
absolute accuracy of the ECC meters was maintained to within ±10 percent
of the original calibration during the year.

A computer processes the data from the mean hourly data submitted
by each observing location to the Techniques and Standards Group. An
example of the computer printout for a month's data for Boulder is shown
in figures 15 and 16. The format of figure 15 includes the mean hourly
surface amounts, the daily average, and the largest of the hourly values
for each day. The form shown in figure 16 includes the daily average
amounts, the daily maximum, the time of the maximum, and the duration of
any peaks of 100 nanobars or more.

Currently, copies of the computer printout of the partial pressure
of surface ozone are available through the Techniques and Standards
Group, ARL, NOAA, Boulder, Colo. The processed data are also contained
on computer punch cards.

Plans for 1974. In addition to the present ECC meter measurements
at the GMCC locations, the McMillan Electronics Corporation chemiluminescent ozone meter is being used at Boulder and the South Pole. This
instrument is being tested as a possible second method for measuring
surface ozone at the GMCC observations. It operates on the principle of
the photometric detection of the chemiluminescence resulting from the
flameless reaction of ethylene gas with ozone. Tentative plans are
also, to conduct tests on a Dasibi Corporation ultraviolet absorption
ozone photometer; it measures ozone by detecting the absorption by ozone
of ultraviolet light at 253.7 nm.

The various measuring techniques will also be compared with the 1
percent, neutral buffered potassium iodide method of measuring ozone, in
order to establish a summary standard against which all instruments will
be compared.

4.1.4 Freon-11 (CCl_3F)

An objective of the GMCC program is to assess the relative contributions of natural sources and of man-made sources to the background
concentrations of trace constituents. Separating most of the climatically active gases into these two sources is very difficult. CO_2, O_3,
and NH_3 are all produced by man and by nature. The sources are unevenly
distributed and of varying strengths. Further, the sinks and removal
processes are highly variable. As one example, CO_2 uptake by biota is
much more efficient in the Northern Hemisphere than in the Southern
Hemisphere because of more biota mass and is further complicated by the
temperature dependent behavior of the oceanic source-sink.

27

PARTIAL PRESSURE OF SURFACE OZONE IN NANOBARS

STATION   BOULDER

MONTH   JUNE   YEAR   1973

EQUIPMENT   ECC

GMT DATE	1	2	3	4	5	6	7	8	9	10	11	12	13
1	46.7	38.9	26.8	37.5	47.7	40.9	39.0	38.4	34.1	27.7	19.5	16.0	15.0
2	36.4	35.5	35.0	32.1	23.7	28.2	24.8	21.9	18.9	19.4	13.6	13.6	14.6
3	38.9	37.4	25.7	23.3	29.2	26.7	28.2	25.8	29.2	29.7	33.1	33.1	36.0
4	30.2	26.3	20.9	16.1	12.2	20.9	22.4	20.4	16.5	17.0	19.0	26.8	26.8
5	39.0	32.2	24.4	36.1	39.5	34.7	34.3	35.7	35.9	36.9	40.7	41.2	35.9
6	18.6	20.0	15.1	21.5	24.4	25.9	26.9	26.4	26.4	26.4	23.0	21.1	18.6
7	25.5	22.5	18.1	26.0	29.4	31.9	33.8	33.8	32.9	31.4	30.4	29.5	29.0
8	33.4	22.6	20.5	24.0	25.5	27.0	26.5	26.0	26.5	26.5	25.0	19.6	22.6
9	65.9	47.3	31.1	33.6	36.6	34.2	30.8	25.9	24.4	25.0	22.0	17.5	20.6
10	42.0	34.9	32.9	27.9	26.8	20.6	21.7	22.3	21.3	23.9	22.9	25.5	25.6
11	36.7	33.1	28.9	23.5	13.9	15.6	18.3	20.5	22.7	23.3	26.5	29.3	25.1
12	39.2	35.4	31.0	20.5	20.6	23.9	24.5	27.4	28.5	28.6	28.1	27.5	15.3
13	36.7	35.0	26.4	17.9	22.5	15.0	15.8	19.7	16.8	18.0	20.4	18.1	12.8
14	27.3	24.4	17.3	18.5	19.1	19.7	19.6	19.8	16.2	16.4	16.3	14.5	12.7
15	30.1	30.2	23.4	23.4	31.5	34.1	33.5	33.6	32.4	30.5	29.3	28.7	25.7
16	56.0	55.5	55.0	54.4	55.1	60.5	60.5	59.9	59.9	59.9	66.0	44.2	49.0
17	42.3	43.3	40.4	36.5	39.0	35.6	39.1	39.1	34.2	38.2	38.2	37.8	32.3
18	35.3	43.4	45.0	44.5	44.1	45.2	43.7	40.7	37.7	41.3	41.9	43.0	41.5
19	42.4	41.9	38.4	40.0	43.7	46.4	47.5	45.0	39.3	40.4	39.9	39.0	37.5
20	32.8	34.5	27.5	26.5	29.8	25.6	18.1	18.1	24.0	25.1	23.5	24.1	19.8
21	43.9	43.9	31.0	36.4	30.0	23.6	28.4	31.2	32.3	32.9	31.8	30.8	27.1
22	30.5	30.4	28.2	25.5	26.4	23.2	21.0	27.1	28.1	26.9	25.2	23.1	21.9
23	37.7	27.7	21.6	17.6	20.1	21.1	21.1	23.0	23.5	23.5	23.5	25.0	23.0
24	34.7	27.3	18.3	24.9	29.7	29.7	30.7	30.7	33.6	33.6	33.6	33.6	31.6
25	34.5	27.1	16.9	18.3	23.7	30.6	31.6	34.0	33.5	28.7	32.1	28.7	29.7
26	29.3	25.9	21.0	24.9	28.3	29.8	29.8	29.8	26.4	28.3	28.8	27.3	21.5
27	38.6	29.3	22.5	21.0	21.5	23.4	23.4	24.9	23.5	22.5	21.5	18.1	18.1
28	29.8	25.9	19.1	17.2	15.7	19.2	20.2	20.2	19.3	20.3	20.3	16.9	14.5
29	21.5	22.5	20.5	18.1	12.7	11.2	14.2	10.3	15.6	18.6	16.1	18.1	18.6
30	44.1	37.7	32.3	39.2	32.8	26.5	23.0	20.6	20.5	19.6	22.1	19.1	15.7
31													
MEAN	36.7	33.1	27.4	27.7	28.6	28.3	28.4	28.4	27.8	28.1	27.8	27.0	24.7

Figure 15.   Example of one month's surface ozone data at Boulder, Colo.

28

PARTIAL PRESSURE OF SURFACE OZONE IN NANOBARS

STATION BOULDER

MONTH JUNE   YEAR 1973

EQUIPMENT ECC

GMT DATE	14	15	16	17	18	19	20	21	22	23	24	MEAN	MAX
1	22.4	35.0	45.2	49.1	-1.0	-1.0	-1.0	55.9	60.7	62.2	45.7	38.3	62.2
2	15.5	19.4	20.9	22.3	21.4	28.2	32.1	34.5	39.3	36.4	34.5	26.1	39.3
3	40.4	42.9	42.8	40.9	38.0	33.1	38.0	40.4	36.0	27.3	27.3	33.5	42.8
4	22.4	23.3	25.8	31.6	33.1	33.1	36.5	41.8	40.3	37.9	36.4	26.6	41.8
5	33.4	35.9	33.5	29.6	28.7	25.3	23.8	25.8	26.3	21.5	19.0	32.0	41.2
6	16.7	27.5	28.0	28.5	28.5	26.5	26.5	26.5	26.5	25.1	19.2	23.9	28.5
7	29.5	32.4	34.9	33.9	36.4	38.9	29.5	29.1	27.1	28.1	27.1	30.0	38.9
8	13.7	19.1	53.5	44.7	48.6	56.9	46.1	52.0	59.4	62.3	73.1	35.6	73.1
9	30.7	42.3	38.8	41.9	61.7	56.3	80.7	70.7	56.5	46.9	40.4	41.0	80.7
10	25.6	26.2	29.4	28.4	36.8	35.9	38.0	37.6	37.6	35.6	38.3	29.9	42.0
11	18.5	15.8	23.0	24.6	30.7	32.4	33.6	34.2	35.3	36.5	36.6	26.6	36.7
12	15.2	20.9	26.6	28.9	48.2	44.9	38.1	32.5	28.5	33.7	35.5	29.4	48.2
13	17.5	26.9	32.8	33.4	37.6	55.3	73.0	73.7	62.6	55.5	39.1	32.7	73.7
14	10.3	11.5	16.4	21.9	21.9	28.0	28.7	33.0	33.7	33.1	30.1	21.2	33.7
15	27.6	38.9	41.5	37.1	35.9	39.1	41.1	48.7	50.1	50.2	40.0	35.3	50.2
16	49.1	53.4	53.4	52.8	50.1	47.4	46.9	47.3	46.8	42.7	41.2	53.6	66.0
17	27.9	31.9	33.9	41.5	48.5	48.6	46.1	44.7	46.2	43.8	35.2	39.3	48.6
18	42.0	43.1	42.2	43.8	44.3	47.0	50.1	47.1	44.6	46.2	43.6	43.4	50.1
19	35.4	33.9	35.0	35.6	32.5	32.6	33.2	36.9	38.6	39.7	35.5	38.7	47.5
20	19.9	24.2	30.7	38.8	41.5	43.2	38.9	37.9	42.2	40.7	41.8	30.4	43.2
21	21.2	25.0	26.1	36.8	47.5	45.4	44.9	45.4	45.4	36.5	34.9	34.7	47.5
22	18.2	28.8	31.4	38.0	50.1	47.4	49.8	51.2	62.3	59.6	47.2	34.2	62.3
23	23.5	27.4	33.9	29.9	29.9	33.3	35.3	36.3	40.2	36.2	37.2	29.0	40.2
24	30.6	36.0	41.9	38.0	35.5	35.5	36.0	34.5	35.9	33.5	34.4	32.7	41.9
25	18.9	18.9	35.6	53.2	50.8	34.1	33.7	31.2	29.8	32.7	28.8	30.7	53.2
26	28.3	29.8	33.2	32.2	33.2	32.2	34.7	33.7	38.1	38.5	42.0	30.3	42.0
27	16.1	18.6	24.9	29.9	33.7	39.1	41.6	47.9	39.2	39.1	34.2	27.9	47.9
28	17.9	24.3	30.7	33.7	32.2	26.8	35.7	40.1	30.4	28.9	28.5	24.4	40.1
29	20.5	25.9	43.9	41.5	70.8	97.1	76.6	61.9	60.5	55.6	54.6	34.5	97.1
30	20.6	27.9	32.9	41.2	50.0	56.4	81.9	80.5	68.7	57.4	49.1	38.3	81.9
31													
MEAN	24.3	28.9	34.1	36.1	39.9	41.4	43.1	43.8	42.9	40.8	37.7	32.8	51.4

Figure 15.   Example of one month's surface ozone data at Boulder, Colo. — continued.

29

```
PARTIAL PRESSURE OF SURFACE
OZONE IN NANOBARS

STATION  BOULDER

MONTH  JUNE       YEAR  1973

EQUIPMENT  ECC

DAY    MEAN   MAX**   TIME    DURATION*
                      (GMT)    (MIN)
  1    38.3   74.3    2305
  2    26.1   40.8    2250
  3    33.5   44.8    1950
  4    26.6   42.8    2225
  5    32.0   44.4    0345
  6    23.9   35.3    1540
  7    30.0   44.8    1830
  8    35.6   82.9    2330
  9    41.6   94.9    1925
 10    29.9   46.1    0045
 11    26.6   39.9    0005
 12    29.4   56.7    1745
 13    32.7   80.2    2000
 14    21.2   36.2    1850
 15    35.3   55.2    2205
 16    53.6   67.2    1045
 17    39.3   50.1    1850
 18    43.4   52.7    1705
 19    38.7   51.7    0625
 20    30.4   45.9    1805
 21    34.7   53.4    1820
 22    34.2   65.2    2250
 23    28.0   46.8    0005
 24    32.7   MSG
 25    30.7   59.6    1645
 26    30.3   44.4    2340
 27    27.9   53.3    2030
 28    24.4   42.6    2030
 29    34.5  121.1    1958         10
 30    38.3   96.6    1945
 31
MEAN   32.8   57.6

** OTHER OBSERVATIONS OF 100NB OR MORE
DAY AMOUNT TIME DURATION*
 29   110.4 1940      10
 29   108.9 1905       5

*  DURATION GIVEN FOR VALUES OF
   100NB OR MORE
```

Figure 16. *Example of surface ozone data summary.*

To disentangle these relationships, we need global measurements of an inert tracer whose source is wholly anthropogenic or wholly natural and whose production is known, quantitatively, with some precision.

Candidate materials should be relatively inert, minimally soluble in sea water with the resulting long (10 years or greater) residence time in the atmosphere. Further, if the tracer is sampled in remote locations, extremely low concentration must be detectable. Dr. James E. Lovelock (1971, 1972, 1973) has suggested Freon-11 ($CCl_3 F$) as such a tracer.

A collaborative program in the Air Resources Laboratories was established to build and operate electron capture gas chromatographic detectors (Lovelock et al., 1971). Dr. Lovelock provided the initial system and consultation on methods. The gas chromatographic (GC) equipment is operated by the Air Resources Laboratories Field Research Office at Idaho Falls, Idaho, under the direction of Messrs. Thayne Thompson and C. Ray Dickson in support of a variety of tracer experiments. The material is apparently only man made and as such represents a unique identification of man's activities. Its production in 1973 was about 2.5×10^{11} g annually and to date approximately 2×10^{12} g have been produced. Approximately 98 percent of this material is produced and released in the Northern Hemisphere. Thus, it is a unique tracer especially for identifying inter-hemispheric transport. A program was begun in September 1973 to collect samples of Freon-11.

Lovelock et al. (1971) have determined that the background concentration of Freon-11 in the Eastern Atlantic was about 65×10^{-12} parts per part. Measurements in uncontaminated air above the Los Angeles inversion indicate approximately a 70×10^{-12} concentration. Collection and detection of these very low concentrations creates many expected and unexpected difficulties. Table 6 shows the individual flask concentrations measured at the three locations in September through December 1973. The data record appears to be very "noisy," and we have not to date separated real signals from possible sampling contamination or analysis uncertainties. However, the lowest values observed do not seem to be too different from background levels observed elsewhere. Two special points should perhaps be made. Most of the sampling at Mauna Loa has been done in the late forenoon or early afternoon. These times are typical of an upslope flow that often comes from the populated regions of Hawaii. Thus, the possibility of sampling locally released Freon-11 has not been eliminated. (Sampling in the nighttime downslope air should assist in clarifying this situation.) High values have been observed at Barrow, Alaska, with concentrations $> 120 \times 10^{-12}$. However, recent work by the Naval Research Laboratory (Wilkniss, 1974) has shown that high concentrations of Freon-11 penetrate well into the Arctic, so that the possibility of trans-polar transport cannot be ruled out. A duplicate flask sampling program to test the sampling procedure is being instituted at selected stations in 1974 and a revised procedure to collect pressurized flask samples is being developed.

Table 6. Station Data Results 1973

Date		Freon-11 Concentration pptV	σ	CCl₄ Concentration pptV	σ
		Barrow, Alaska			
Sept.	16	69.5	1.6	42.2	2.2
	29	99.8	4.0	107.2	3.1
Oct.	11	412.7	52.4	53.7	4.2
	19	133.0	4.9	138.4	2.7
Nov.	2	128.1	5.5	69.8	2.5
	13	86.6	7.9	52.7	4.5
	20	67.8	6.7	22.1	3.8
	30	152.7	18.0	57.2	3.6
Dec.	8	70.7	7.5	62.9	4.0
		Cape Matatula, Samoa			
Sept.	25	84.0	2.0	50.4	7.0
Oct.	4	75.1	3.6	52.7	3.3
	15	79.2	4.6	55.2	3.0
	23	135.8	15.6	109.5	12.0
	30	84.1	6.8	70.3	10.7
Nov.	7	164.9	15.2	79.9	3.8
	14	157.6	14.1	72.1	7.8
	21	63.7	10.6	66.8	5.2
	28	71.3	5.4	71.0	3.7
Dec.	5	154.4	4.5	119.8	6.0
	19	71.2	6.6	76.3	4.3
		Mauna Loa, Hawaii			
Sept.	19	100.0	4.7	42.2	4.1
	28	103.9	11.4	N.D.	-
Oct.	5	129.4	7.2	150.3	8.2
	12	66.4	1.8	75.2	4.5
	19	73.6	4.1	39.2	3.9
	26	78.2	6.9	40.7	5.2
	29	100.2	1.6	42.6	2.0
Nov.	7	395.2	32.9	14.1	0.7
	23	69.2	3.3	61.2	4.3
	26	69.5	6.5	59.3	6.8
Dec.	7	85.5	10.5	67.4	9.4
	12	87.5	7.1	64.3	5.2
	21	98.6	8.9	N.D.	-

N.D. = not detected < 5 ppt

A summary of the 1973 program, equipment, analysis, and results follows.

Three sampling stations were chosen to represent different latitudes: Pt. Barrow, Alaska at 72°N; Mauna Loa, Hawaii at 19°N; and Cape Matatula, American Samoa at 14°S.

The sampling method collects ambient air in stainless steel flasks with high purity shut-off valves. Six flasks are assigned to each station to accommodate a rotation scheme. On a weekly basis, a flask is sent in padded mailing tubes with data sheets to the stations. The flask is then opened to the ambient air, resealed, and returned to Idaho for Freon-11 and CCl_4 analysis. Upon completion of five replicate chromatographic determinations, each flask is cleaned, numbered, re-evacuated, and returned to the station. This complete procedure requires 6 weeks.

In addition to this program, a cooperative effort with Dr. J. E. Lovelock has started to relate meteorological data to the Freon-11 concentrations measured at Adrigole, Ireland (50°51'N, 9°44'W). The automated electron capture gas chromatograph of Dr. Lovelock provides daily observations of CCl_3F and CCl_4. Meteorological trajectories calculated backwards in time and space from Adrigole, Ireland, using a comprehensive data base supplied by the U.S. Air Force and a computer program developed by Mr. Jerome Heffter of the Air Resources Laboratories (the details of which will be reported in other publications) have been related to concentration data. Figure 17 shows the results of associating particular trajectories with specific concentration values. The very much higher concentration associated with transport from Europe as compared with the Eastern Atlantic background concentration levels (of order 65×10^{-12}) lends confidence to the trajectory computations. The
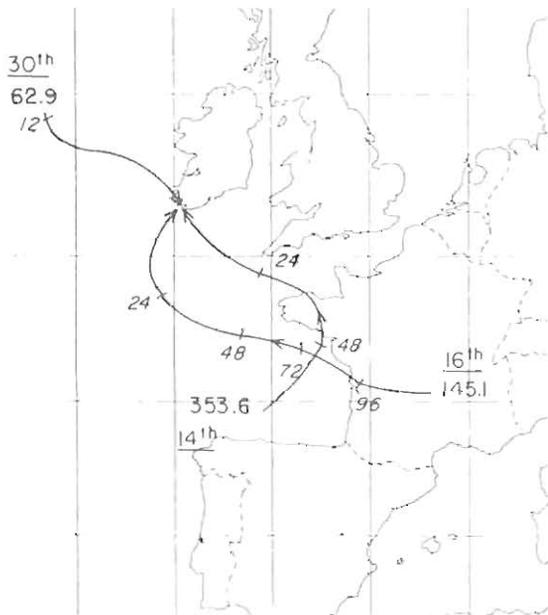
Figure 17. Concentration of CCl_3F $(x10^{-12})$ as given trajectory (data underlined) at Adrigole, Ireland, August 1973.
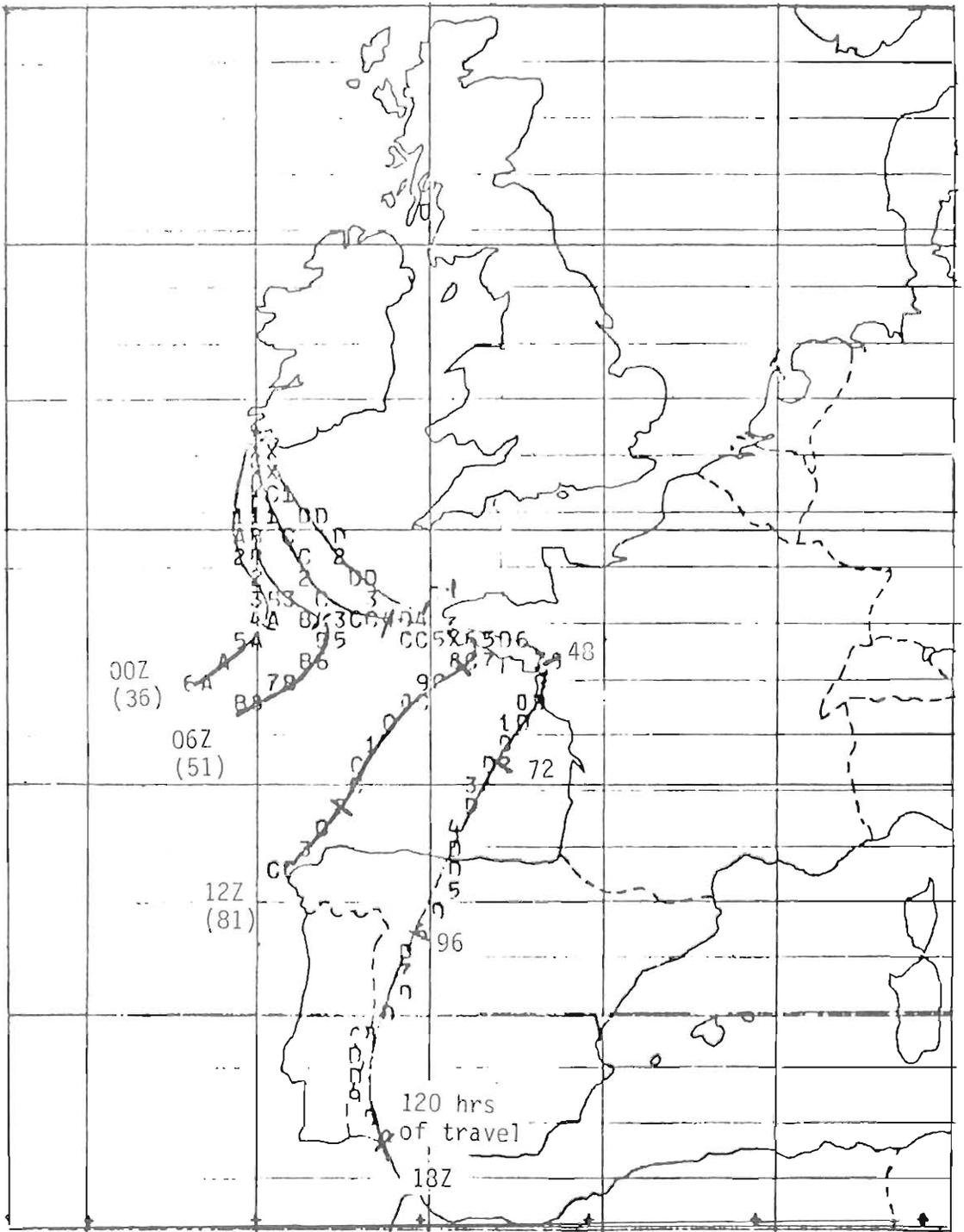
Figure 18. Computer produced trajectories for September 8, 1973.

34

study is only in its initial stages; however, tentative conclusions are that more than a single concentration measurement is required within a 24-hour period since the meteorological trajectories may originate from a wide distribution of potential sources. A portion of the day may represent air from clear areas, although the remainder may be from populated areas. Figure 18 shows the computed produced trajectories for September 8, 1973, which illustrate the shift from "clean" to "polluted" sources.

Equipment. The flasks were factory cleaned in trichloroethane vapor and the cleaning procedure used before initial station use is a 2-hour immersion in 5 molar phosphoric acid, distilled water rinse, ethanol rinse, and ultra purity nitrogen purge. They are then evacuated to 50 Microns of mercury pressure using a Precision Scientific, Model 25, vacuum pump and Cenco thermocouple gage No. 94178.

Figure 19 shows the sampling flask and mailing apparatus. The valve inlet has a plastic protective cap over it during shipment.

Figure 20 is the data sheet sent with each cylinder. It is completed in duplicate at the time of sampling; one is retained for the station records, the other returned with the cylinder.

Figure 21 is a diagram of the electron capture chromatograph. Specific components (see numbers on fig. 21) follow:

1. Ultra high purity nitrogen supplied by Liquid Air, Inc., in 2400 psi cylinders.

2. High purity two-stage stainless steel regulator Series 3800, Matheson Gas Products.

3. Micro-volume valve supplied by Carle Instruments, Inc., of Fullerton, California. Catalog No. 2016 which has two sample loops, 1/16 inch (0.16 cm) gas connections, and purge manifold. 5 cc sample loops are used.

4. Swagelok reducing union from 1/4 FPT to 1/6 inch (0.16 cm) tube.

5. Hoke shut-off valve connected by 1/4 inch (0.64 cm) stainless tubing to a Precision Scientific Model 25 vacuum pump and Cenco thermocouple vacuum gage No. 94178.

6. Fine metering valve, Series S, with 1/8 inch (0.32 cm) Swagelok inlet and outlet and vernier handle, by Nupro Company, Cleveland, Ohio.

7.   2.5 meter long spiral wound column made of 1/4 inch (0.64 cm) stainless steel. The column packing is Carbowax 400/Porasil F "Low K" Durapak made by Waters Associates, Inc. of Farmington, Mass.

8.   Cylindrical ionization chamber (brass). Internal dimensions are 1.1 cm long with a 1 cm diameter. Ionization source is 15 mCi of Ni-63 electroplated on platinum foil.

9.   Fischer and Porter low flow flowrator, Model 10A1339Ni2AXGM, calibrated for nitrogen gas.

10. Temperature test chamber, Model 1060 RB2 by Delta Design, Inc., of San Diego, Calif. Faceplate modified to house chromatograph column and detector within. It is an air thermostat.

11. Note shown on the figure. Moseley Autograph dual pen recorder, model 7100B to record chromatograph output.
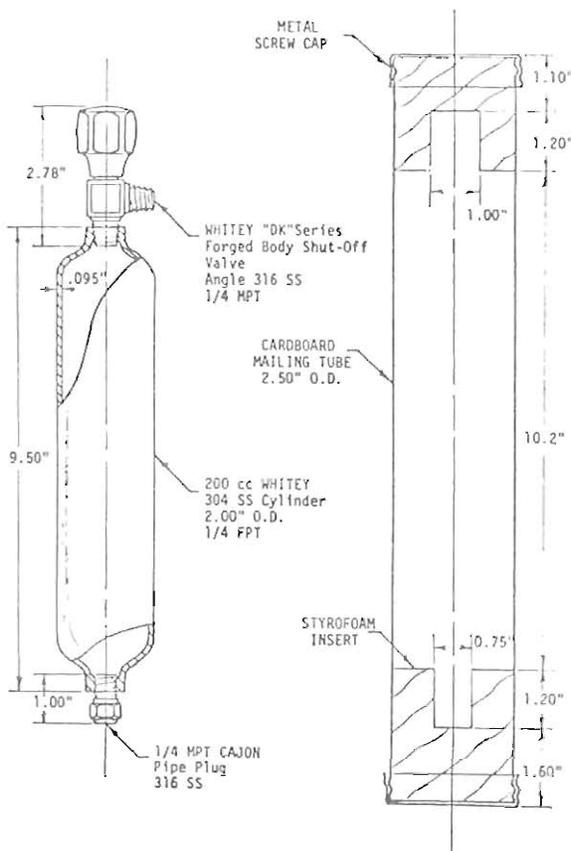
Figure 19. Sample flask and mailing sleeve.   *Figure 20. Data sheet Freon-11 sampling.*

Figure 22 outlines the electronic package of the pulse model electron capture system.

Figure 21. Diagram of electron capture chromatograph apparatus.

1. Nitrogen Carrier Gas
2. Nitrogen Regulator
3. Gas Sampling Valve
4. Sample Flask Hook-up
5. Vacuum Pump Valve
6. Flow Control
7. Column
8. Electron Capture Detector
9. Flowmeter
10. Thermostat

Figure 22. Electron capture detector and electronics.

Data for 1973. On the chromatograph, data were extracted by hand measurements of peak height and width at half height then corrected to a Gaussian curve.

Dry air densities were determined from data sheet values of temperature and pressure and used to convert peak areas to parts per part by volume.

A typical clean air chromatogram is shown in figure 24.

Improvements for 1974. The increasing sample load requires many hours of hand extracting data from charts. The most accurate and time saving method of data handling is by electronic digital integrators. At the end of 1973, an integrating system (Autolab IV made by Spectra-Physics) was under trial examination.

During preliminary checks, cylinders gave consistent results when evacuated and opened to local air. However, because of the variability observed in the station samples, the sampling procedure will be changed.

4.2 Aerosols

4.2.1 MLO Ruby Laser Radar (LIDAR) System

During 1973, the MLO lidar continued in experimental and developmental phases. The lidar data have been useful in interpreting data collected by other observatory instruments, e.g., detection of a thin cirrus layer to determine its possible effect on radiometric data, or use of horizontal shots to measure aerosol spatial uniformity. These techniques were experimented with during 1973.

The primary purpose of the MLO lidar system is to accurately measure atmospheric scattering properties. These measurements, in addition to other MLO data, will lead to greater understanding of the physical and chemical dynamics of the atmosphere, e.g., the relationship of Junge layer strength and ozone levels (Fiocco and Grams, 1964; Rosen, 1968). Equally important are any trends that are observed; they may indicate a climatic change. For example, volcanoes injecting gasses and aerosols, aerospace operations, releasing contaminants, or man-made pollutants could all change the stratospheric albedo.

Lidar makes it possible to quickly measure the one-dimensional 180° backscatter properties of the atmosphere above the observatory. These measurements would be extremely difficult with direct sampling techniques.

Although the direct output of a lidar analysis is the atmospheric backscattering coefficient (BC), use of standard aerosol size distributions allows us to estimate aerosol number and mass density.
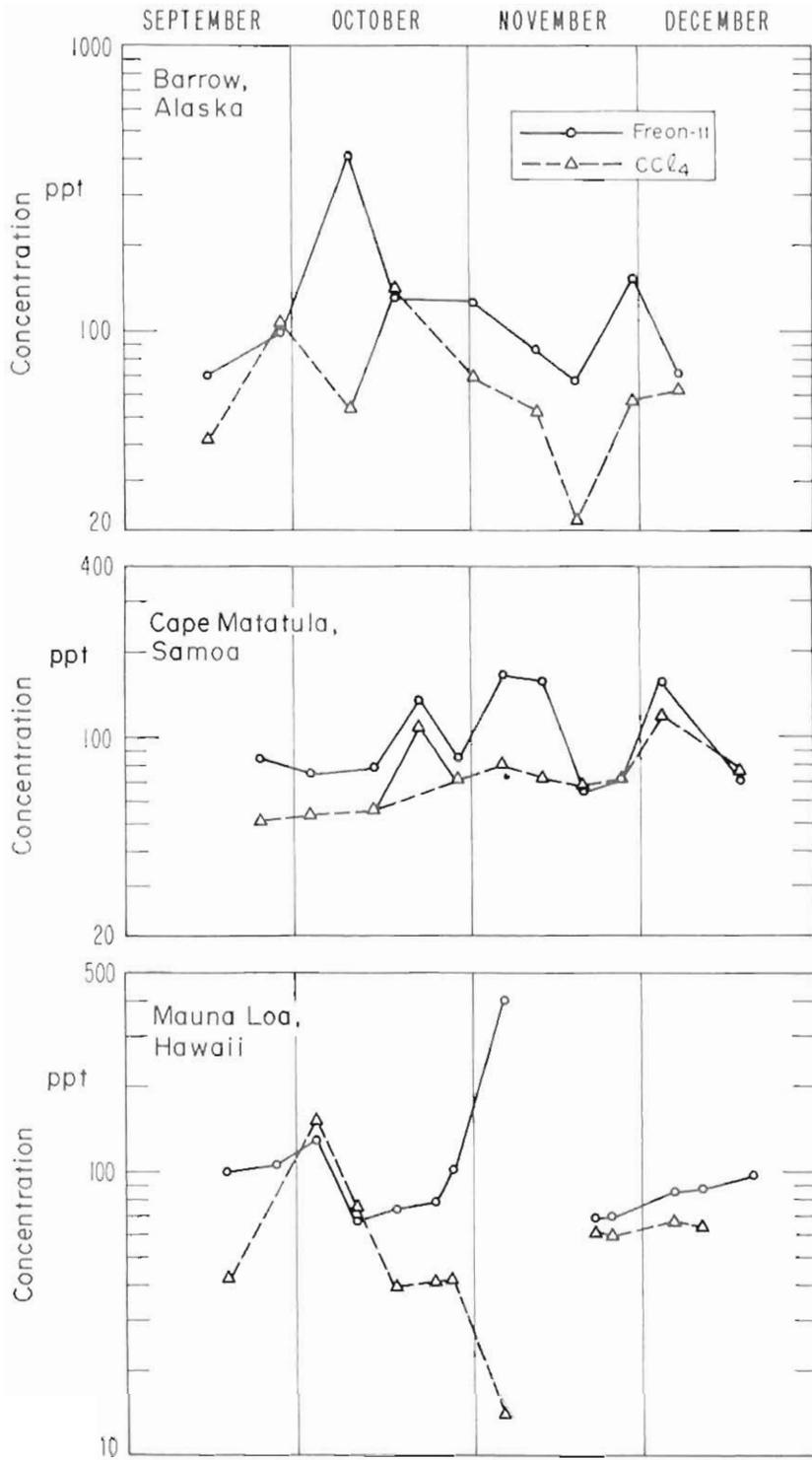
Figure 23. Freon-11 and CCl_4 values observed at Barrow, Samoa, and Mauna Loa.
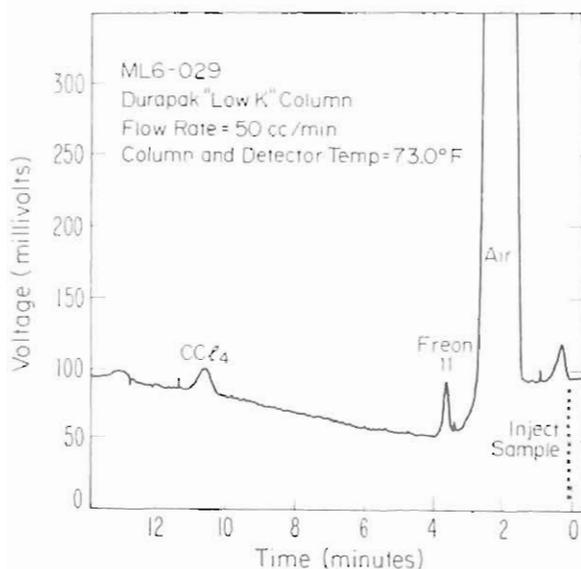
Figure 24.   A typical chromatogram.

During 1973, biweekly profiles of the BC were produced. The data were parameterized by showing the heights and maximum BC of the aerosol layers found. There was always at least one prominent layer in the stratosphere and, on some occasions, one in the troposphere.

System description. The MLO lidar system is located at the observatory at 3.4 km elevation. The setting is appropriate in that the atmospheric clarity reduces degradation of the outgoing and incoming signal, and the nearness of the stratosphere reduces inverse-square losses. A block diagram of the system appears in figure 25.

The laser pulses are emitted by the Apollo ruby laser [1]. The angular width of the beam is about 10 mrad. The pulse rate is 2 ppm, and the pulse duration is 30 nsec. Pulse energy is about 1 to 2 J with a peak power of about 10^8 W. The outgoing pulse passes through a 1 m collimator that reduces stray light in the dome. The light backscattered from the atmosphere is collected by two telescopes, [2] and [3]. The optical axes of the system are aligned using a large white-card target about 300 m away. The collected light passes through 10 Å bandpass filters, which reduce background light, and is detected by multiplier phototubes, [5] and [6]. The resulting electrical signal is filtered to produce an integration time of about 0.5 μsec and is then recorded using an oscilloscope-camera combination, [12]. The range resolution is about 75 m. A small amount of the laser light is collected and detected at [8]. The integrated output is displayed at [11] and is used to normalize the return signals.

40
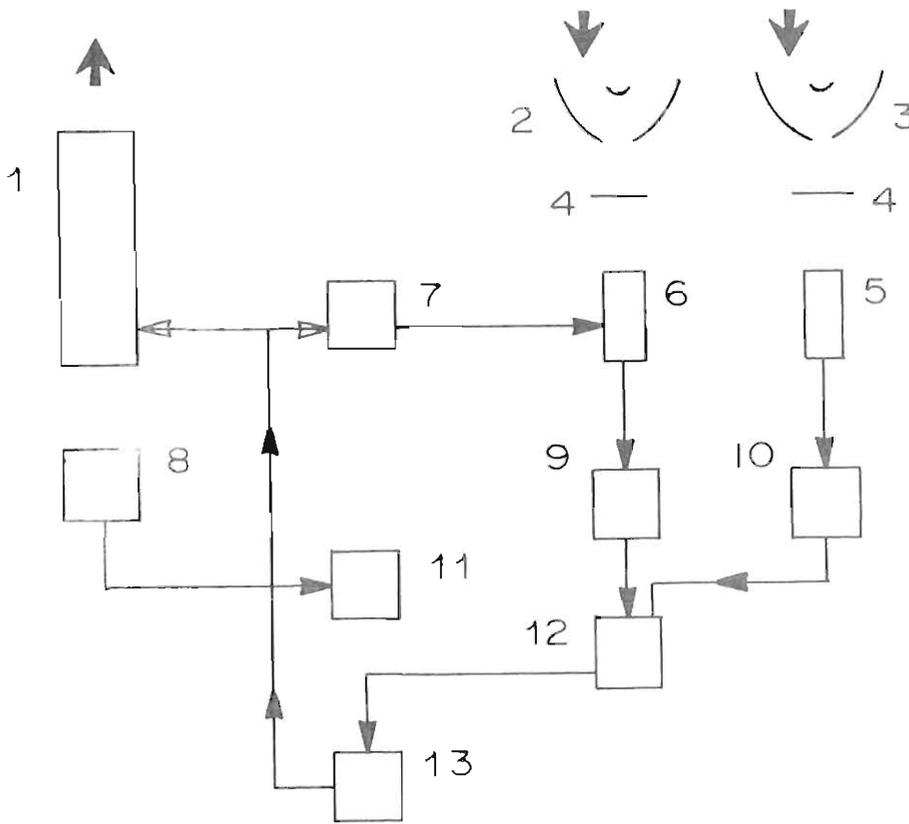
Figure 25. (1) Apollo 3J, 30 ns ruby laser, 2 ppm; (2) 40 cm dia. reflector long range telescope; (3) 8 cm dia. reflector short range telescope; (4) Interference filter, 10A bandpass at 6943A; (5,6) Short and long range photomultiplier tubes, RCA 7265; (7) Long range PMT modulator unit; (8) Photodiode laser output detector; (9,10) low pass electrical filter, 4 mHz cutoff; (11) Digital voltmeter; (12) Dumont dual-beam oscilloscope with Polaroid camera unit; (13) timing unit.

A typical photo output from the system is shown in figure 26. Each photograph contains a graph that is proportional to voltage V(r). Time usually ranges from 0 to 200 μsec for useful signal return. By averaging several photographs, we can obtain the best V(r) which is denoted $V(r)_{av}$.

The photos are now analyzed manually, although this will soon be done by a computer (activated July 1974). Each trace is digitized at 10 μsec intervals using a ruler. This gives 10 values for each trace on each photo. There are five photos per evening, resulting in 100 values each evening. The data are then organized and analyzed to provide the relative BC at each altitude.
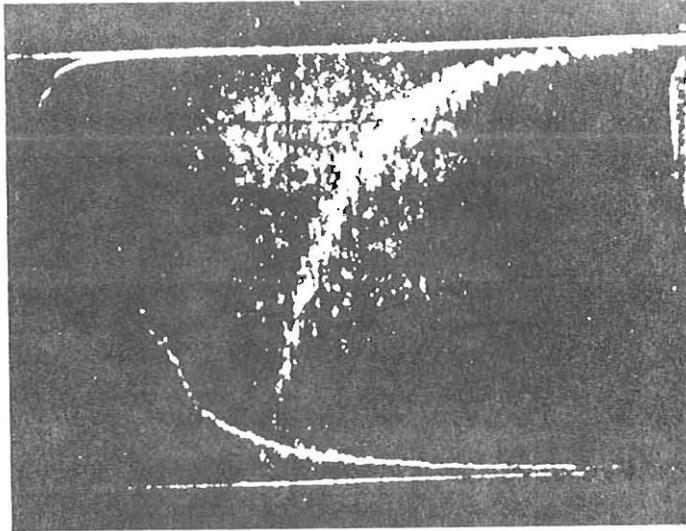
Figure 26. *Lidar output signals.* *Upper trace is long-range telescope output.* *Sweep rate is 20 μsec/cm, which corresponds to a range of 3 km/cm.* *During first 60 μsec, PMT gain is reduced by modulator unit.* *Bright straight line is baseline.* *Lower trace is short-range scope.* *Sweep rate is 5 μsec/cm, or 750 m range per cm.* *On both traces, time increases to right.* *On upper trace, positive signal is downward.*

Data analysis. The backscattering coefficient (BC) at range r is given by (Barrett and Ben Dov, 1967)

$$C_{sca}(r) = K \ V(r) \ r^2/J$$

in which $C_{sca}(r)$ is the backscattering coefficient, r is the range, K is a lidar system constant, $V(r)$ is the voltage on the oscilloscope from range r, and J is the laser output energy. This expression assumes:

1. The aerosols are randomly distributed
2. The aerosols occupy the entire cross section of the beam at all heights.
3. The attenuation along the path is negligible.
4. Pertinent range is past the region of parallax.
5. Detection system is linear.
6. Laser pulse duration is short compared with system integration time.

The analysis procedure is as follows: The baseline for each trace is adjusted to produce pure Rayleigh scattering at 30 km and some also at a lower level (usually in the neighborhood of 14 km). This is a standard

technique that is presently unavoidable (Barrett and Ben Dov, 1967). The Rayleigh BC computed from the tropical standard atmosphere is then subtracted from the experimental BC to yield the aerosol contribution to the BC.

Results for 1973. A biweekly operating schedule was used in 1973. The data are displayed in figure 27. No data are available before March 22. During the data period, a layer was always apparent at about 20 km. There may have been other minor layers present, but the photographic analysis technique is too inaccurate to give fine detail. There appeared to be a steady, lowering trend in the height of this layer until about the middle of October, when the height abruptly increased to about 23 km. No systematic variation occurred in the maximum BC of this layer. The maximum BC averaged about 1.5×10^{-8} m^{-1} $ster^{-1}$ with two large variations in July and October.

In late spring, a second layer appeared at a lower altitude. Tropopause folding is a possible interpretation of this phenomenon. This layer averaged about 17 km msl during the rest of the year, with a slight upward trend. The maximum BC's were a little greater on the average than those of the higher layer. They increased during the year, apparently reaching maximum values about mid-fall. This lower layer may have been present in March but not detectable in the data.

These BC's average about a factor of three higher than those measured by Stanford Research Institute (SRI) at Menlo Park, California, during the same period.

The results support those of Rosen (1968) in which he found a strong latitudinal variation of the Junge layer strength with a maximum at the lower latitudes. Another possible interpretation of these data is that the "clean" layer of the atmosphere used to calibrate the lidar returns at the more northern latitudes is contaminated with aerosol.

A tropical standard atmosphere was used in this analysis, but radiosonde data to 30 km are available for the sampling dates. Currently the data are being reanalyzed using the actual temperature profiles. These results will appear in the next summary report (No. 3).

Operating difficulties. Two problems existed during 1973. The first was electronic noise in the signal channels, and the second was erratic output of the laser.

The signal return from the stratosphere is extremely weak, so that any noise present will cause extreme error in the stratospheric BC's. There was a small amount of 60-cycle pickup present during most of 1973, which, because of the electronic configuration, could cause a shift of the zero baseline and thereby distort the stratospheric returns. The approach to this problem was to set an arbitrary baseline to produce pure Rayleigh scattering to 30 to 33 km msl. This assumption may or may not be good. In any event, the 20 km data appear reliable since a slight
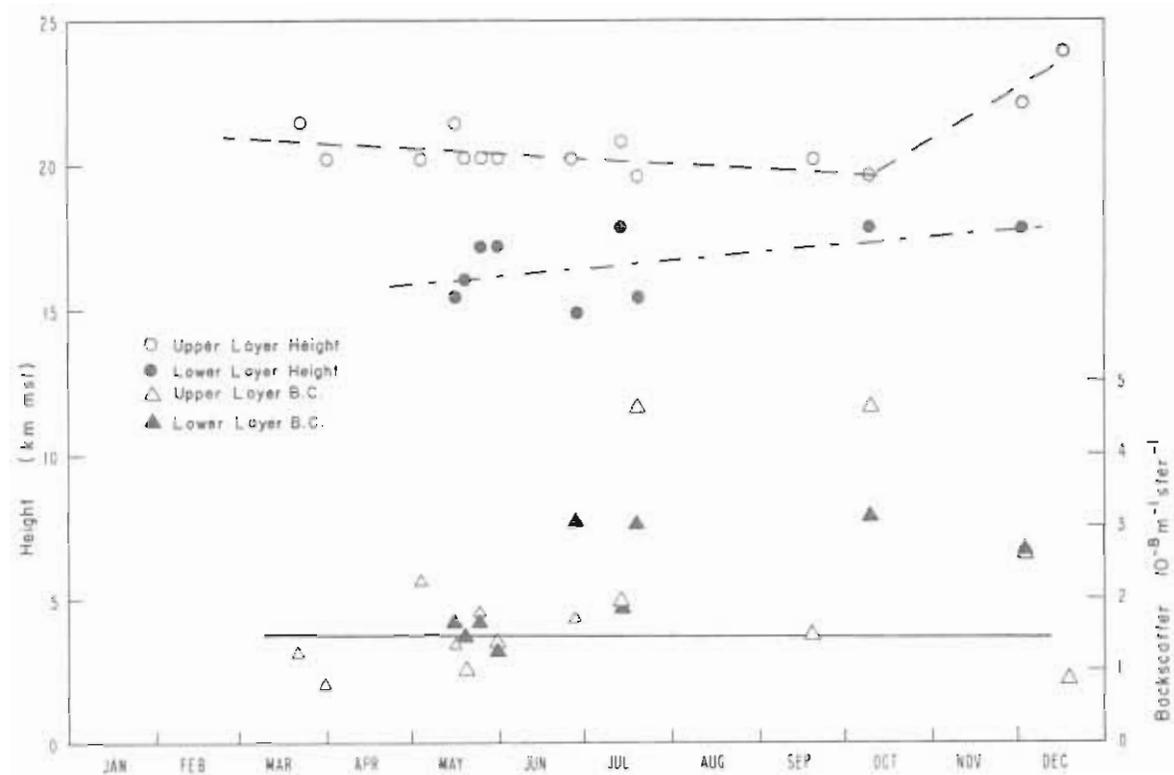
Figure 27. Height and peak BC of aerosol layers above Mauna Loa during 1973. Heights are shown on left scale and BC on right. Open circles show height of upper layer and open triangles show BC at peak. Dark circles show height of lower layer and dark triangles show BC. Lines were drawn in to show trends of data.

44

baseline shift that caused a drastic percentage change at 33 km produced only a small percentage change at 20 km. However, there could be greater systematic error at higher altitudes.

The second problem was trying to keep the laser output high during 1973. One difficulty was the optical surfaces being contaminated by water deposits, dust, etc. A second difficulty was the temperature cycling of the laser head causing misalignment of the optical surfaces.

Future developments. During 1974 there are plans to:

1. Add an electronic digitizer to the signal channel.
2. Add a digital computer to the system so that the results can be automatically calculated and plotted in real time.
3. Add a photon counting system so that the stratospheric signals can be processed more accurately and our maximum altitude extended.
4. Conduct a series of experiments using the lidar and the nephelometer to measure the MLO surface aerosol total scatter to backscatter ratio.
5. Experiment with using the lidar to measure atmospheric transmission as a function of altitude and compare it with the radiometric determination.
6. Compare lidar measurements with twilight measurements.
7. Increase lidar operations to a weekly schedule.
8. Continue to analyze and reduce system noise.

4.2.2 *Aitken Nuclei Concentration at MLO*

Aitken nuclei may be defined as atmospheric aerosols that act as condensation nuclei at supersaturations of 300 percent. Since Aitken nuclei have diameters of about the wavelength of visible light or smaller ($\sim 10^{-7}$ to 10^{-4} cm); they cannot be detected directly but must be detected after they act as condensation nuclei and grow to water droplets of diameter $\sim 5 \times 10^{-4}$ cm (5 μ). This is done by having a humidified air sample suddenly expand, producing a supersaturation of ~ 300 percent, and then measuring the concentration of water droplets formed either by a direct count or by the attenuation or scattering of an incident light beam.

Gardner Counter. The Gardner Counter is a small, portable instrument that operates on the principle described above; i.e., a humidified air sample is suddenly expanded into an adjacent evacuated chamber. The attenuation of a light beam passing through the air sample is measured by a photocell, and calibrated in terms of aerosol concentration in nuclei/ cm^3.

A Gardner counter has been operated hourly at Mauna Loa since 1967. Gardner counter No. 912 (NBS No. 140687) was operated throughout 1973; data are shown in table 7. Figure 28 shows monthly averages of the 1000

45

Table 7. Aitken Nuclei at MLO, Monthly Averages 1973

Month	1000			1100			1200			1300			1400		
	n	$\bar{y}$	σ	n	$\bar{y}$	σ	n	$\bar{y}$	σ	n	$\bar{y}$	σ	n	$\bar{y}$	σ
January	20	323	154	21	327	119	21	307	75	21	396	180	21	460	275
February	17	404	127	17	446	162	17	503	346	16	971	848	15	880	644
March	20	252	119	21	297	146	21	328	273	21	310	162	21	325	177
April	15	341	137	16	462	285	16	423	324	17	374	221	13	478	448
May	21	365	157	23	376	152	22	493	323	21	612	495	21	606	401
June	21	384	211	21	382	183	20	602	407	19	614	396	19	601	322
July	19	404	169	21	393	153	21	585	405	21	711	392	19	8c9	613
August	23	344	126	23	389	132	23	632	542	22	935	767	20	1165	830
September	15	342	129	15	317	97	14	639	574	14	1012	1257	14	1086	963
October	21	338	99	21	401	141	20	488	242	20	652	296	19	837	655
November	19	661	438	21	737	542	20	685	478	20	720	422	18	867	503
December	17	346	78	18	356	100	18	427	268	18	511	512	18	628	669
Annual Average	228	377	208	238	407	249	233	511	495	230	637	544	218	751	753
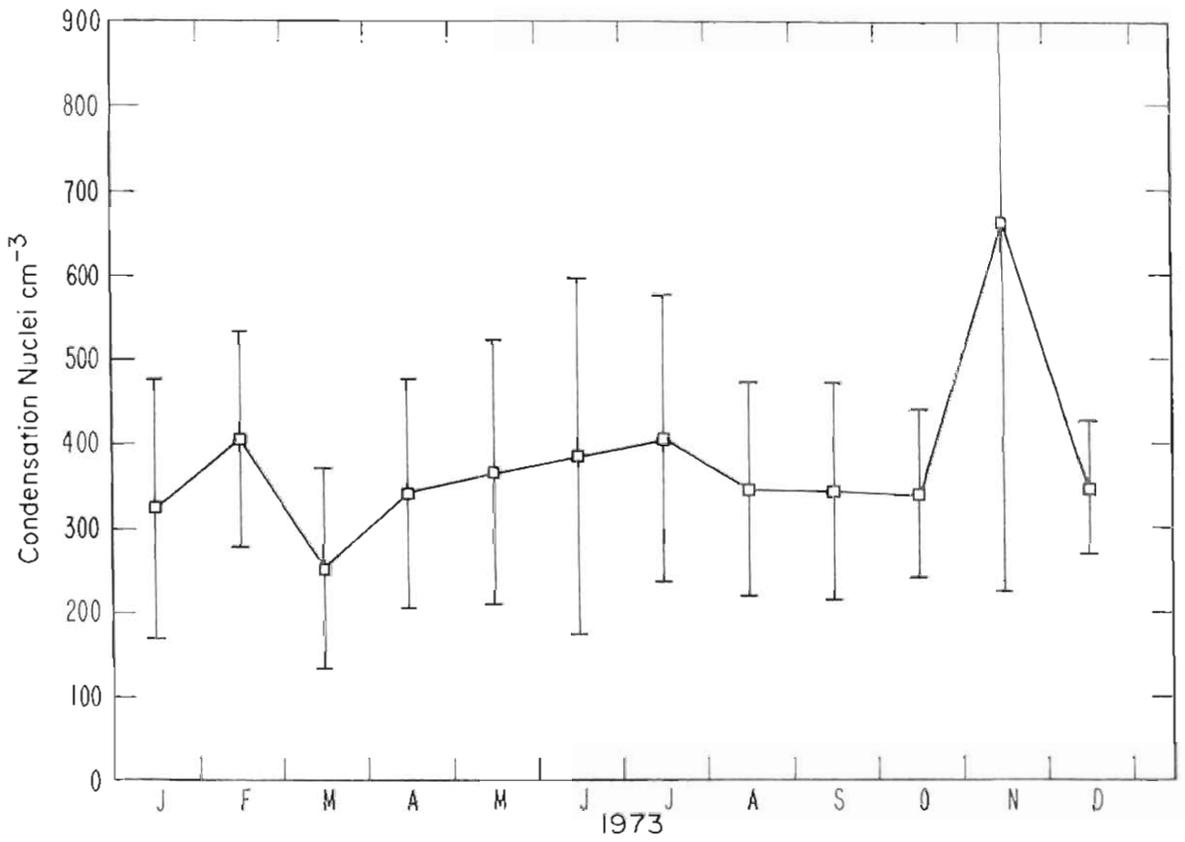
Figure 28. Condensation nuclei at MLO using Gardner counter No. 912 for 1973. These are the 1000 hr of observations from table 7. Vertical bars are standard deviations.

hourly observations. However, it is of doubtful merit to attempt to draw conclusions from the clean air values because the sensitivity limit of the Gardner counter is about 200 nuclei/cm³. The annual averages are interesting in that they clearly show the arrival of the upslope wind bringing island air from below the inversion (fig. 29).

Gardner counter No. 912 was compared with Pollak condensation nuclei counter No. 13 at MLO; the calibration curve is shown in figure 30.

Pollak Counter. The Pollak counter is a non-portable instrument that measures condensation nuclei by light attenuation. A humidified air sample is pressurized with filtered air to a certain overpressure and then allowed to expand to ambient pressure. The attenuation of a light beam as condensation nuclei grow into water droplets is again measured by a photocell and compared with a calibration table.

Pollak counter No. 13 at MLO was loaned to the GMCC by Austin Hogan of the State University of New York at Albany and will serve as the MLO standard. The calibration table is included as table 8 for low concentration values (less than 3,000 nuclei/cm³). There was no regular Pollak counter measurement program in 1973; however, a few measurements were made at MLO and these are given in table 9.
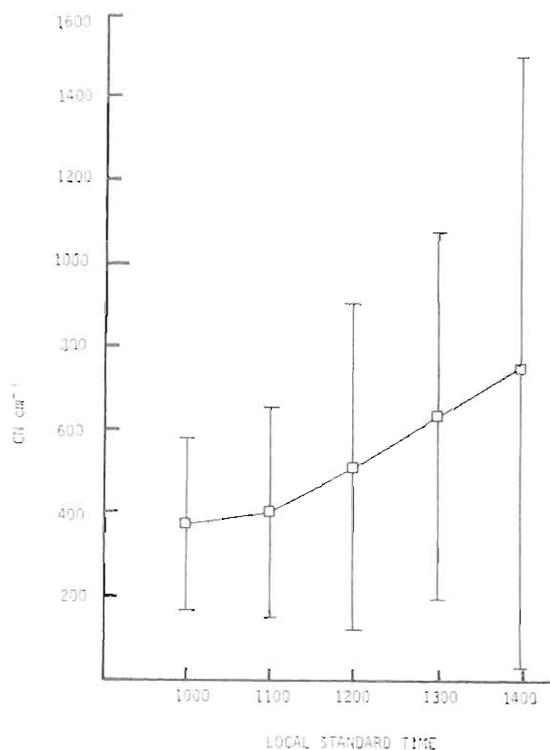
Figure 29. Annual averages (1973) of condensation nuclei at MLO using Gardner counter No. 912.

48
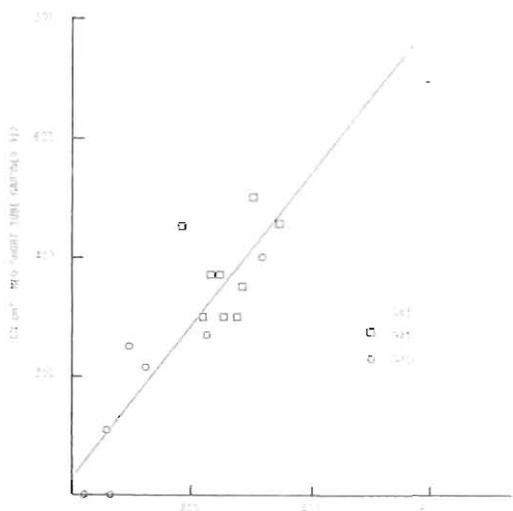
Figure 30. Comparison of the MLO Gardner counter No. 912 and MLO Pollak No. 13. ▢ indicates measurement on ambient aerosol; ○ indicates NiCr aerosol in Mylar bag. Comparison was performed Oct. 6 to 8, 1973.

G.E. Condensation Nuclei Automatic Counter. The G.E. is an automatic counter that samples CN at the rate of 5/sec. A humidified air sample is suddenly expanded and the growth of condensation nuclei into water droplets is measured by light scattering at low scattering angles. A G.E. counter, serial No. 7006, was installed at MLO in July 1973 and produced usable data during Aug. 1 - Sept. 3 and Sept. 12 - Oct. 10. The G.E. data are valuable, of course, because they are obtained on a continuous basis and therefore give information about nighttime condensation nuclei concentrations, which are of primary interest to the GMCC. Unfortunately, this instrument has demanded more maintenance time than expected, resulting in a large amount of down time. Figure 31 shows daily 1000 hr values of condensation nuclei measured by this counter.

Plans. The Pollak counter will play an increasingly important role in Aitken nuclei monitoring. It will be used as the standard at all stations, and an automated version may be developed to produce nighttime measurements. Furthermore, multiwavelength nephelometers will be used to expand the aerosol monitoring capabilities of the GMCC.

4.2.3 *Barrow and Samoa*

Small Particle Survey. Monitoring ambient clean air at a baseline site requires the ability to identify when there is local contamination present in the air being sampled. Various indicators are being used to do this, but the primary method is the aerosol small particle concentration number. The two stations that became operational in 1973, Barrow and Samoa, used a Gardner Counter to monitor aerosol content; Barrow monitored on an hourly basis from 0800 to 1700 hours LT and Samoa on a time-available basis. Manufactured by Gardner Associates, this portable instrument operates on the moistened expansion chamber principle. It has a 0.5 meter expansion tube with a photocell detector and light source at

Table 8. Model 1957 with Convergent Light-Beam

Diameter: 2.5 cm

R	E%	Z	R	E%	Z	R	E%	Z	R	E%	Z
100.0	0.0	0	96.0	4.0	91	92.0	8.0	227	88.0	12.0	420
99.9	0.1	1	95.9	4.1	94	91.9	8.1	231	87.9	12.1	426
99.8	0.2	3	95.8	4.2	97	91.8	8.2	235	87.8	23.2	432
99.7	0.3	5	95.7	4.3	100	91.7	8.3	239	87.7	12.3	438
99.6	0.4	7	95.6	4.4	103	91.6	8.4	243	87.6	12.4	444
99.5	0.5	9	95.5	4.5	106	91.5	8.5	247	87.5	12.5	449
99.4	0.6	11	95.4	4.6	109	91.4	8.6	251	87.4	12.6	455
99.3	0.7	13	95.3	4.7	112	91.3	8.7	256	87.3	12.7	461
99.2	0.8	15	95.2	4.8	115	91.2	8.8	260	87.2	12.8	467
99.1	0.9	17	95.1	4.9	118	91.1	8.9	264	87.1	12.9	474
99.0	1.0	19	95.0	5.0	121	91.0	9.0	269	87.0	13.0	480
98.9	1.1	21	94.9	5.1	124	90.9	9.1	273	86.9	13.1	486
98.8	1.2	23	94.8	5.2	127	90.8	9.2	278	86.8	13.2	492
98.7	1.3	25	94.7	5.3	130	90.7	9.3	282	86.7	13.3	499
98.6	1.4	27	94.6	5.4	133	90.6	9.4	287	86.6	13.4	505
98.5	1.5	30	94.5	5.5	137	90.5	9.5	292	86.5	13.5	511
98.4	1.6	32	94.4	5.6	140	90.4	9.6	296	86.4	13.6	518
98.3	1.7	34	94.3	5.7	143	90.3	9.7	301	86.3	13.7	524
98.2	1.8	36	94.2	5.8	146	90.2	9.8	306	86.2	13.8	531
98.1	1.9	39	94.1	5.9	150	90.1	9.9	310	86.1	13.9	538
98.0	2.0	41	94.0	6.0	153	90.0	10.0	315	86.0	14.0	544
97.9	2.1	43	93.9	6.1	156	89.9	10.1	320	85.9	14.1	551
97.8	2.2	46	93.8	6.2	160	89.8	10.2	325	85.8	14.2	558
97.7	2.3	48	93.7	6.3	163	89.7	10.3	330	85.7	14.3	565
97.6	2.4	50	93.6	6.4	167	89.6	10.4	335	85.6	14.4	572
97.5	2.5	53	93.5	6.5	170	89.5	10.5	340	85.5	14.5	579
97.4	2.6	55	93.4	6.6	173	89.4	10.6	345	85.4	14.6	586
97.3	2.7	57	93.3	6.7	177	89.3	10.7	350	85.3	14.7	593
97.2	2.8	60	93.2	6.8	181	89.2	10.8	355	85.2	14.8	600
97.1	2.9	62	93.1	6.9	184	89.1	10.9	360	85.1	14.9	607
97.0	3.0	65	93.0	7.0	188	89.0	11.0	366	85.0	15.0	615
96.9	3.1	67	92.9	7.1	192	88.9	11.1	371	84.9	15.1	622
96.8	3.2	70	92.8	7.2	195	88.8	11.2	376	84.8	15.2	629
96.7	3.3	73	92.7	7.3	199	88.7	11.3	382	84.7	15.3	637
96.6	3.4	75	92.6	7.4	203	88.6	11.4	387	84.6	15.4	644
96.5	3.5	78	92.5	7.5	207	88.5	11.5	392	84.5	15.5	652
96.4	3.6	80	92.4	7.6	211	88.4	11.6	398	84.4	15.6	660
96.3	3.7	83	92.3	7.7	215	88.3	11.7	404	84.3	15.7	667
96.2	3.8	86	92.2	7.8	219	88.2	11.8	409	84.2	15.8	675
96.1	3.9	89	92.1	7.9	223	88.1	11.9	415	84.1	15.9	683

R	E%	Z	R	E%	Z	R	E%	Z	R	E%	Z
84.0	16.0	691	80.0	20.0	1068	76.0	24.0	1577	72.0	28.0	2250
83.9	16.1	699	79.9	20.1	1079	75.9	24.1	1592	71.9	28.1	2269
83.8	16.2	707	79.8	20.2	1090	75.8	24.2	1607	71.8	28.2	2288
83.7	16.3	715	79.7	20.3	1101	75.7	24.3	1622	71.7	28.3	2308
83.6	16.4	724	79.6	20.4	1112	75.6	24.4	1637	71.6	28.4	2327
83.5	16.5	732	79.5	20.5	1124	75.5	24.5	1652	71.5	28.5	2347
83.4	16.6	740	79.4	20.6	1135	75.4	24.6	1668	71.4	28.6	2367
83.3	16.7	749	79.3	20.7	1147	75.3	24.7	1683	71.3	28.7	2387
83.2	16.8	757	79.2	20.8	1158	75.2	24.8	1698	71.2	28.8	2407
83.1	16.9	766	79.1	20.9	1170	75.1	24.9	1714	71.1	28.9	2427
83.0	17.0	775	79.0	21.0	1182	75.0	25.0	1729	71.0	29.0	2447
82.9	17.1	783	78.9	21.1	1193	74.9	25.1	1745	70.9	29.1	2467
82.8	17.2	792	78.8	21.2	1205	74.8	25.2	1761	70.8	29.2	2488
82.7	17.3	801	78.7	21.3	1217	74.7	25.3	1777	70.7	29.3	2508
82.6	17.4	810	78.6	21.4	1229	74.6	25.4	1793	70.6	29.4	2529
82.5	17.5	819	78.5	21.5	1241	74.5	25.5	1810	70.5	29.5	2550
82.4	17.6	828	78.4	21.6	1254	74.4	25.6	1826	70.4	29.6	2571
82.3	17.7	837	78.3	21.7	1266	74.3	25.7	1842	70.3	29.7	2592
82.2	17.8	846	78.2	21.8	1279	74.2	25.8	1859	70.2	29.8	2613
82.1	17.9	856	78.1	21.9	1291	74.1	25.9	1875	70.1	29.9	2635
82.0	18.0	865	78.0	22.0	1304	74.0	26.0	1892	70.0	30.0	2656
81.9	18.1	874	77.9	22.1	1317	73.9	26.1	1909	69.9	30.1	2678
81.8	18.2	884	77.8	22.2	1330	73.8	26.2	1926	69.8	30.2	2699
81.7	18.3	893	77.7	22.3	1342	73.7	26.3	1943	69.7	30.3	2721
81.6	18.4	903	77.6	22.4	1355	73.6	26.4	1960	69.6	30.4	2743
81.5	18.5	913	77.5	22.5	1368	73.5	26.5	1977	69.5	30.5	2765
81.4	18.6	923	77.4	22.6	1382	73.4	26.6	1995	69.4	30.6	2787
81.3	18.7	932	77.3	22.7	1395	73.3	26.7	2012	69.3	30.7	2809
81.2	18.8	942	77.2	22.8	1408	73.2	26.8	2030	69.2	30.8	2832
81.1	18.9	952	77.1	22.9	1422	73.1	26.9	2047	69.1	30.9	2854
81.0	19.0	963	77.0	23.0	1436	73.0	27.0	2065	69.0	31.0	2877
80.9	19.1	973	76.9	23.1	1449	72.9	27.1	2083	68.9	31.1	2900
80.8	19.2	983	76.8	23.2	1463	72.8	27.2	2102	68.8	31.2	2923
80.7	19.3	993	76.7	23.3	1477	72.7	27.3	2119	68.7	31.3	2946
80.6	19.4	1004	76.6	23.4	1491	72.6	27.4	2137	68.6	32.4	2969
80.5	19.5	1014	76.5	23.5	1505	72.5	27.5	2156	68.5	31.5	2992
80.4	19.6	1025	76.4	23.6	1519	72.4	27.6	2174	68.4	31.6	3016
80.3	19.7	1036	76.3	23.7	1534	72.3	27.7	2193	68.3	31.7	3039
80.2	19.8	1046	76.2	23.8	1548	72.2	27.8	2212	68.2	31.8	3063
80.1	19.9	1057	76.1	23.9	1563	72.1	27.9	2231	68.1	31.9	3087

October 6, 1973				
0832	340 cm^{-3}	T=63	T_p=3	Wind ESE at 20 kt. no up-
0912	325 "			slope, Ci overcast. Un-
1127	382 "			usually clear day.
1140	409 "			
1310	287 "			
1341	256 "			
1343	287 "			

October 8, 1973		
1150	269 cm^{-3}	
1208	376 "	
1453	572 "	Upslope wind arrives.
1501	1330 "	
1519	1548 "	

October 10, 1973	
0709	227 cm^{-3}
0710	251 "
0725	188 "
1000	306 "

October 17, 1973		
1036	256 cm^{-3}	
1039	256 "	
1104	219 "	
1106	264 "	
1109	278 "	
1114	278 "	
1355	524 "	Upslope wind arrives.

October 24, 1973	
1106	223 cm^{-3}
1108	223 "
1303	269 "
1305	247 "
1307	260 "

each end respectively. The following summary identifies the variability in small particle concentration for all air trajectories passing each site, the percentage of good sampling times, and correlation of small particle concentration with other parameters.

The periods of collection used in this summary are from February 1, 1973, through January 31, 1974, for Barrow and from July 1, 1973, through
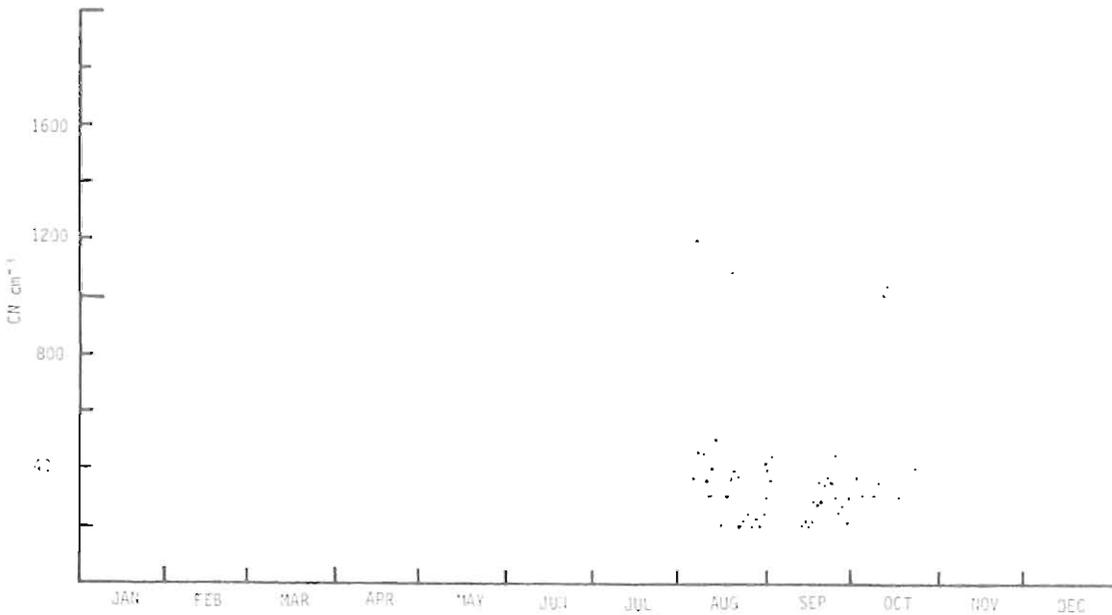
*Figure 31. Daily 1000 hr condensation nuclei values as measured by a G.E.
automatic condensation nuclei counter at MLO during 1973.*

November 30, 1973, for Samoa. These data represent 2290 and 223 hourly
observations, respectively. The Gardner Counter has a threshold value
of 200 detectable particles/cc such that all data entries used are 200
or greater. In many cases, lower values presumably existed. Three
separate Gardner measurements are averaged for each hourly reading.
Known contaminated values — usually caused by automobiles upwind — were
identified and excluded from the data summary. Larger scale contamina-
tion sources such as from the nearby town are however, included in the
data summaries. The locations of the two sampling sites were selected
so that the prevailing winds would not pass near any pollution sources.
The data have therefore been divided into "clean" and "dirty" air quad-
rants by correlation with wind directions. Winds from the north through
southeast via east, excluding velocities of 1.4 m/sec or less, are de-
fined as coming from clean air sources for both stations.

Figures 32 and 33 illustrate the wind rose and associated average
Aitken counts for each wind direction for Barrow and Samoa. Average wind
velocities are indicated on the wind rose bars. The 300 n/cc circle can
be used as a comparison between the two graphs. Note that the Barrow Ob-
servatory can sample clean air flow 66 percent of the time. This fact
has verified that, although the observatory was built near a town and a

53

Figure 32. Barrow wind rose and
Aitken averages February 1973
through January 1974.
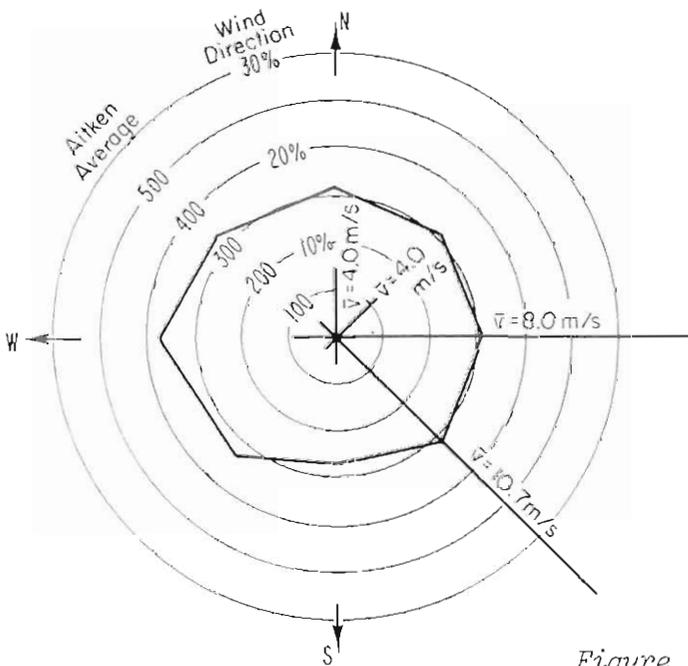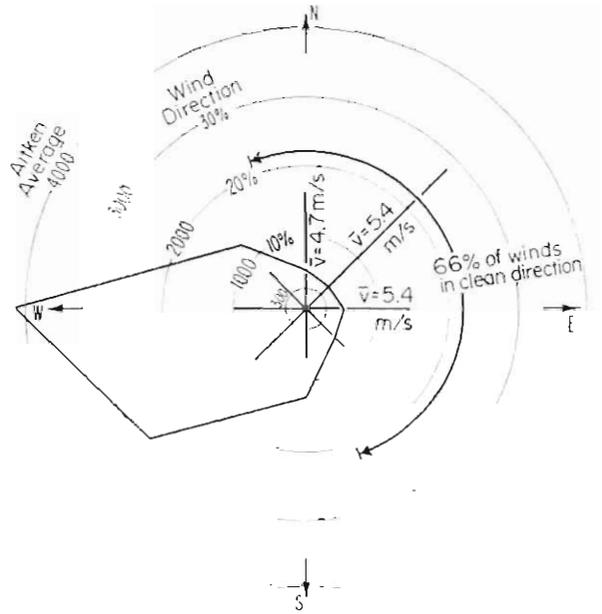
Figure 33. Samoa wind rose and Ait-
ken average July 1973 through No-
vember 1973.

54

large Naval Research facility, by proper placement, it can function as a baseline station.

Table 10 shows the percentage of observation time, by month, when clean air passed the Barrow station, and the average clean air Aitken count. The average Aitken count was usually < 400 n/cc; however, March and July raised the yearly average considerably. A satisfactory explanation for these particularly high concentrations is not obvious; however, the 1973 data are consistent with those from 1972. It is also possible to obtain background air samples from the westerly directions a significant portion of the time. Approximately 30 percent of westerly winds exhibit Aitken concentrations < 350 n/cc. The larger average values for westerly directions are from heavy contamination that commonly occurs. Correspondingly, the standard deviation of the averages are always directly proportional to the average itself and, therefore, not indicated.

Table 10. *The Percent of Winds from a Clean Air Direction and the Corresponding Aitken Particle Count at Barrow.*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'74
Percent of winds from clean air direction												
	85	82	93	87	73	35	44	53	70	66	70	28
Average Aitken Count												
	344	1205	293	340	399	1497	676	367	354	377	274	291

Figure 34 shows the monthly means for Barrow and Samoa. The lower curve of each pair connects the individual monthly means; the upper curve is the 75 percent quartile below which Aitken count 75 percent of the total clean air values lie. The Samoa values (dashed lines) are markedly consistent. The Barrow data show the increased concentrations in March and August; however, note that the mean is < 300 n/cc for 9 out of 12 months and is often lower than concentrations observed in Samoa.

Figure 35, a log-normal plot, shows the significant difference between the average and the mean values of Samoa and Barrow data for the clean air, as well as counts from all directions at Barrow. Use of a log-normal presentation of data means we expect a Gaussian distribution of Aitken concentrations. If a Gaussian distribution can be ascribed physical significance when applied to background aerosol sampling, the bend in the Barrow curves may indicate two separate distributions: a Gaussian clean air distribution and a contaminated air distribution from unknown locations and strengths. The Samoa data showing no heavy tailed distributions means that no pollution sources are upwind of the station and the data are a true background aerosol. Its smaller slope (or standard deviation) is characteristic of a more uniform marine aerosol. The Samoa marine aerosol has a standard deviation of 47. A representative clean air value for Barrow would have a σ = 230. Note that 60 percent
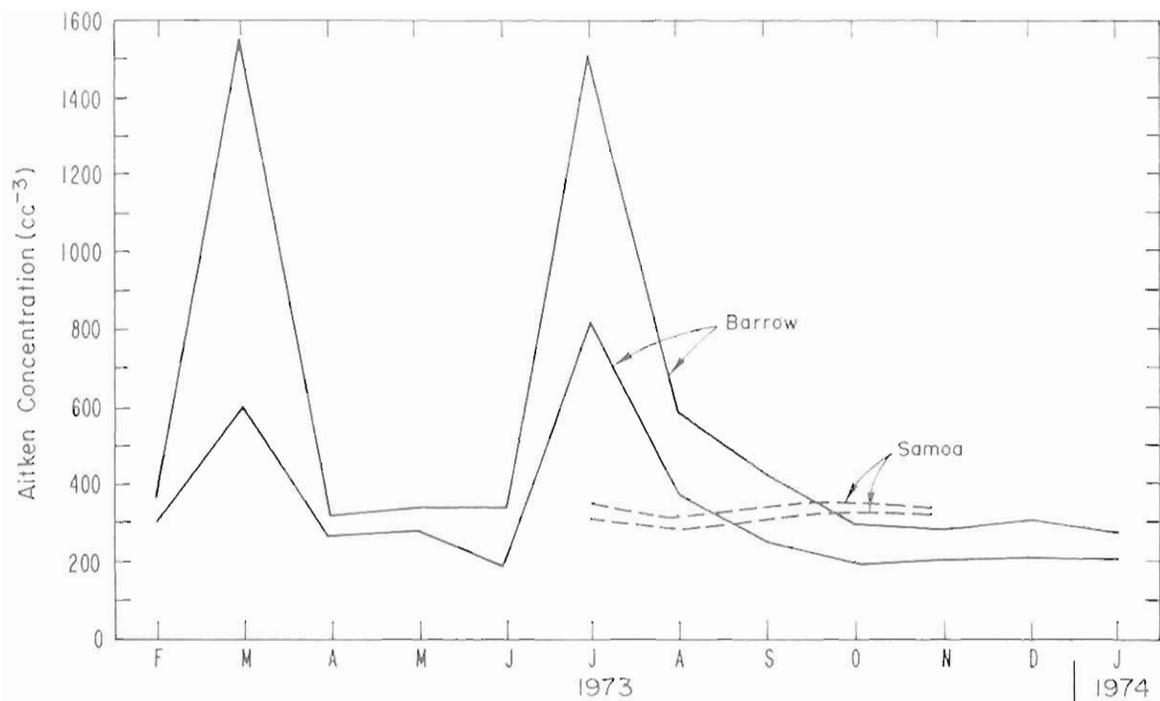
Figure 34.   Monthly AN means for Barrow (Feb. 73–Jan. 74) and Samoa
(July 73–Nov. 73).
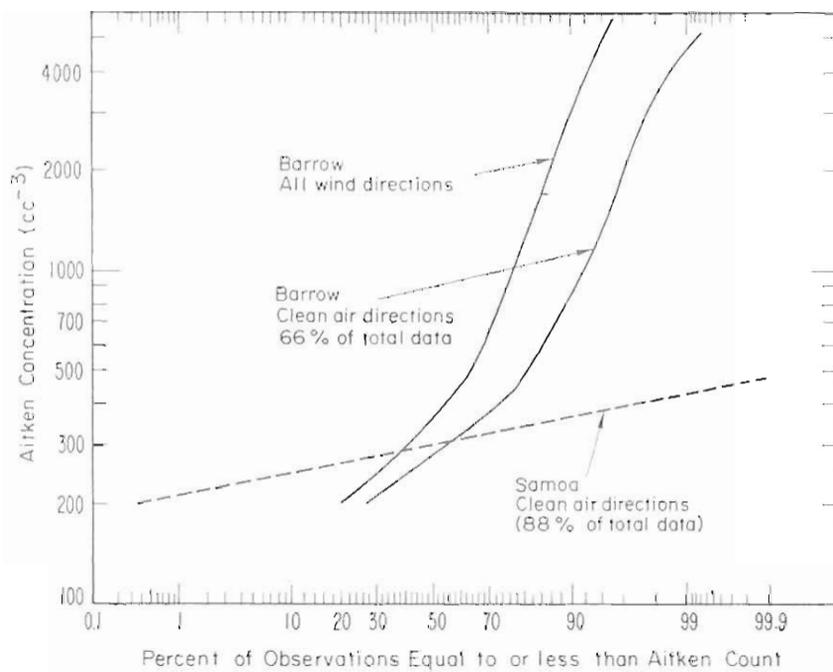
Figure 35.   Log normal plot of Barrow and Samoa AN content distribution.

of the easterly winds at both Barrow and Samoa have Aitken nuclei concentrations of 312 or less.

Correlations between various parameters were sought in order to reflect aerosol behavior and dynamics in the data. At Samoa, the sparse data made several possible correlations uncertain; some comparisons indicated no relationship. The latter included the Aitken concentration number versus wind velocity, rain or no rain, time of day, or amount of cloud cover. The sampling height being 25 meter above the sea may remove much of the interdependency in these parameters indicated by other researchers.

At Barrow, ..relations had more significance, but the inter-dependency of the par ters requires more study to isolate the true influence of a particular rameter. During fog, the Aitken average was significantly lower, specially considering that fog largely occurred during light wind conditions when Aitken averages are usually high. Fog occurred 80 percent of the time when winds were from the clean air directions, yet 61 cases with fog had an average Aitken count one-half that of the clean air average. Blowing snow occurred generally with winds from the north and northeast and showed significantly higher than normal Aitken averages. Rain, drizzle, and snow showed little correlation with Aitken counts measured at the same time. Cloud cover also showed no correlation except that clear days had higher aerosol concentrations than expected. Monitoring the hourly Aitken averages throughout the day displays the working pattern of the Barrow camp in the total averages. After 0800 hours LT, the Aitken count increased, decreased significantly at noon, and increased again in the afternoon. Wind velocity affects the Aitken concentration systematically as illustrated in figure 36.

The marked decrease with velocity is significant because average wind velocities vary only slightly with wind direction.
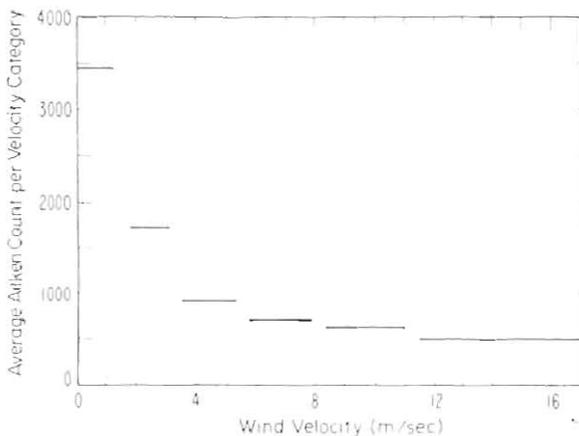
Figure 36. Barrow wind velocity vs. Aitken concentration February 1973 through January 1974.

4.3 Meteorology

4.3.1 Mauna Loa

Mauna Loa Observatory has a relatively mild climate for its elevation, 3.4 km msl. The observatory is near the top of the average vertical extent of the northeast trade wind regime as well as in the northern portion of the latitudinal belt of these trades. Therefore, the observatory experiences an annual variation in winds, type and amount of cloudiness, and presence of the trade wind inversion with the yearly migration of the trade wind belt. The trades and trade inversion are stronger and more persistent in the summer than in the early spring and late fall.

A regular diurnal wind regime influences the general climate at the observatory. This is manifested by a warm daytime upslope flow and a colder downslope flow at night caused by diurnal heating and cooling of the mountain slopes. The upslope flow ordinarily brings up moist subinversion air from below the observatory, while the nighttime downslope flow draws down clean upper tropospheric air from above. This local diurnal weather regime permits an afternoon maximum of cloudiness, moisture, and precipitation, but the nights and mornings are generally cloud free and dry.

Figure 37 gives the annual variation of temperature at the observatory. Virtually half of the year had no temperature below freezing, but showed an unusual number of days of ≤ 0°C. This is reflected in its unusually low average maximum temperature (table 11). On the other hand, June showed an unusually high number of days with temperatures > 16°C, which is also reflected in its high average minimum temperature (table 11). The January set a 13 year record by being warmer than any previous January.

Figure 38 shows the monthly amounts and the number of days having 0.25 mm of precipitation. Overall, 1973 had only 87 percent of the 13-year average. Only July, November, and December exceeded their normal amounts. Note that for 8 months about half of each months total fell in one 24 hour period.

In figure 39 the winds at the observatory are stratified into two categories: when the observatory is under the influence of an easterly flow, and when it is under the influence of a westerly flow. At other times, no set pattern's observed or the diurnal wind regime directions (north for daytime and south for nighttime) mask out the general synoptic flow. The definition of easterly flow is met when 95 percent of the hourly averages had an easterly component in the wind regardless whether an up- or downslope component also occurred. This classification indicates the trade wind regime. The definition for westerly component is identical to the former, and this regime indicates the mid-latitude westerlies extend to the latitude of the observatory. The westerlies
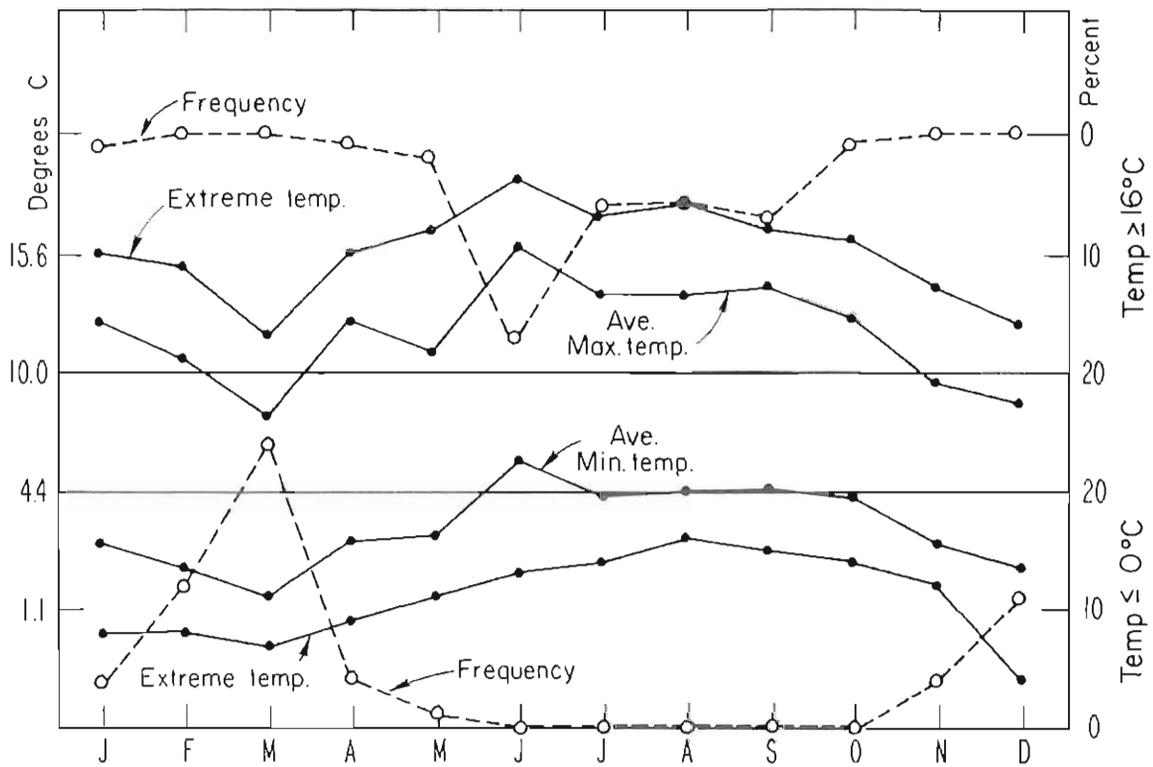
Figure 37. Monthly average and extreme maximum and minimum
temperatures at Mauna Loa Observatory in 1973. (Read on scale
at left.) Frequency of days with temperatures equal to or
above 16°C and equal to or below 0°C. (Read on scale at
right.)
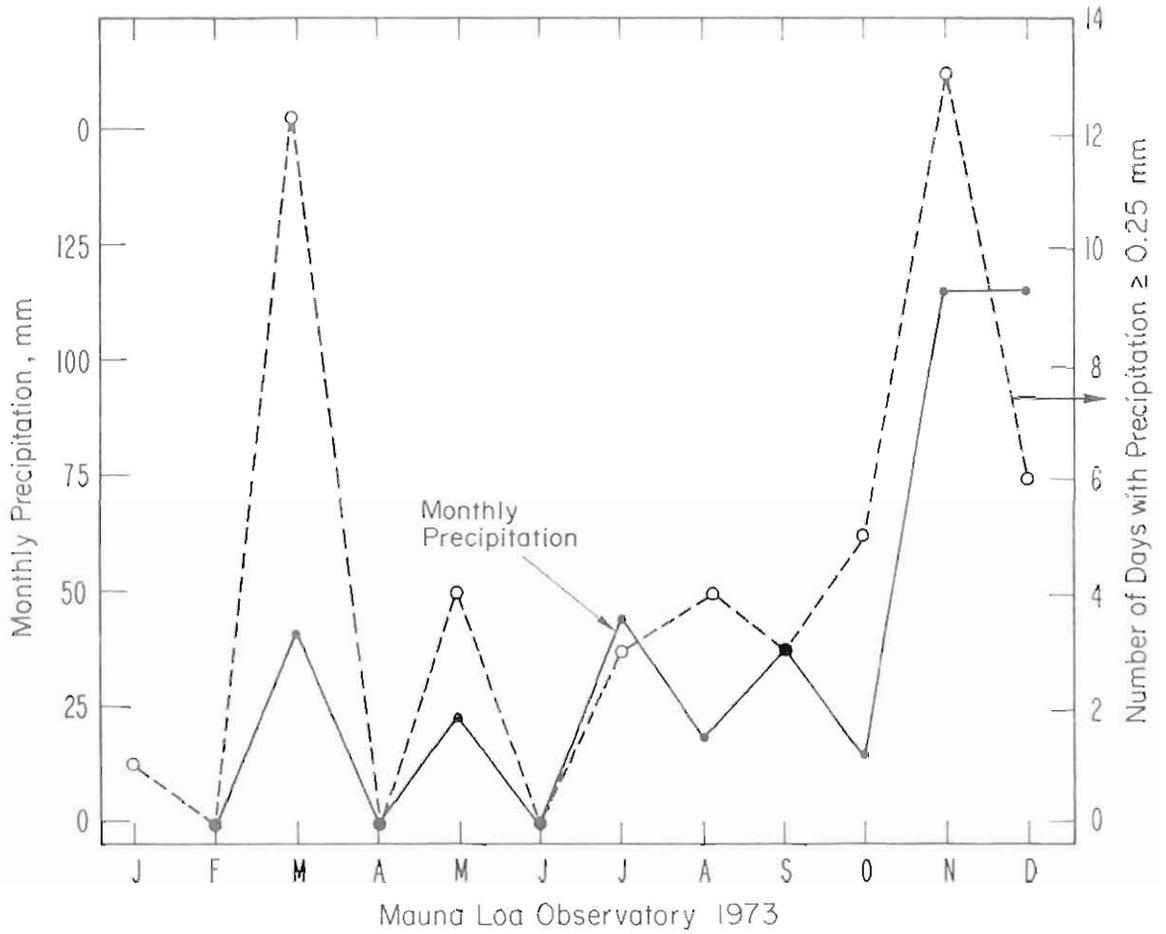
Figure 38. The monthly amounts of precipitation at MLO (mm); the number of days with precipitation below 0.25 mm is plotted by the circles.
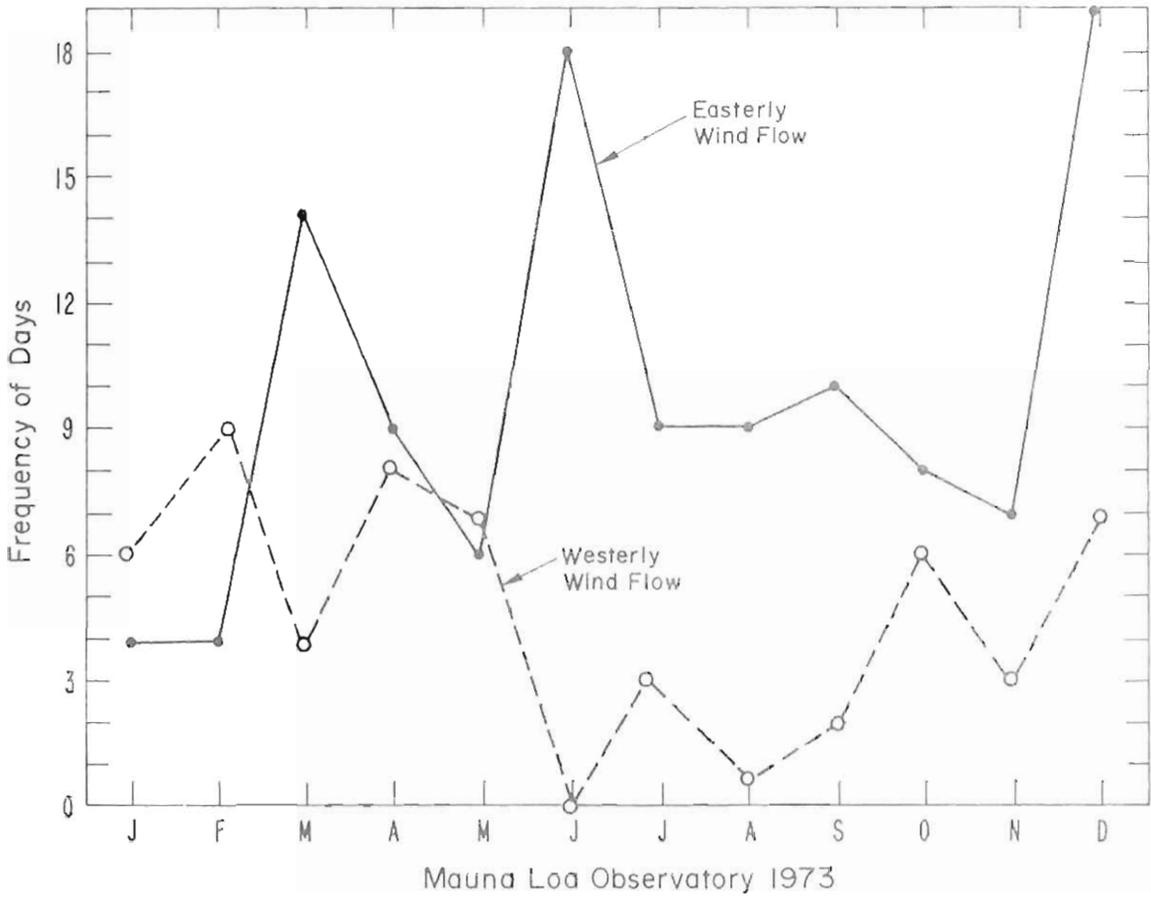
Figure 39. The frequency of days with prevailing winds from the east and from the west.

Table 12. Cape Matatula Climatology for 1973.

1973	Avg. Temp. (°C) Daily Max.	Min.	Monthly	Precipitation (cm) Total	Max.*	Day Date	RH (%)	Wind (m/sec) Resultant Speed	Dir.	Mon. Avg.	Fastest Mile Speed	Dir.	Day	Cloud Cover** Clear	Part. Cldy	Cldy
Jul.	27.2	24.4	25.8	13.49	4.90	28	94.2	6.5	100°	7.5	16.5	E	4	0	14	17
Aug.	28.1	24.6	26.5	11.71	2.08	4,26	86.0	7.1	120	8.6	16.1	SE	5,19	1	17	13
Sep.	28.8	25.1	27.3	5.64	1.19	26	91.4	5.2	100	6.6	13.0	E	10,22	2	17	11
Oct.	27.5	24.0	26.3	27.38	4.52	20	88.7	8.5	130	9.8	21.9	SE	9	0	9	22
Nov.	27.7	23.9	26.0	37.08	6.17	8	93.4	2.5	080	7.0	18.8	W	6	0	7	23
Dec.	29.3	24.6	26.8	30.10	5.08	1,2	89.8	2.4	080	4.5	10.7	SE	15	1	12	18
Average	28.1	24.4	26.4	125.40	6.17	8	90.6	5.1	110	7.3	21.9	SE	9	4	76	104

*In 24 hours.
**Number of days.
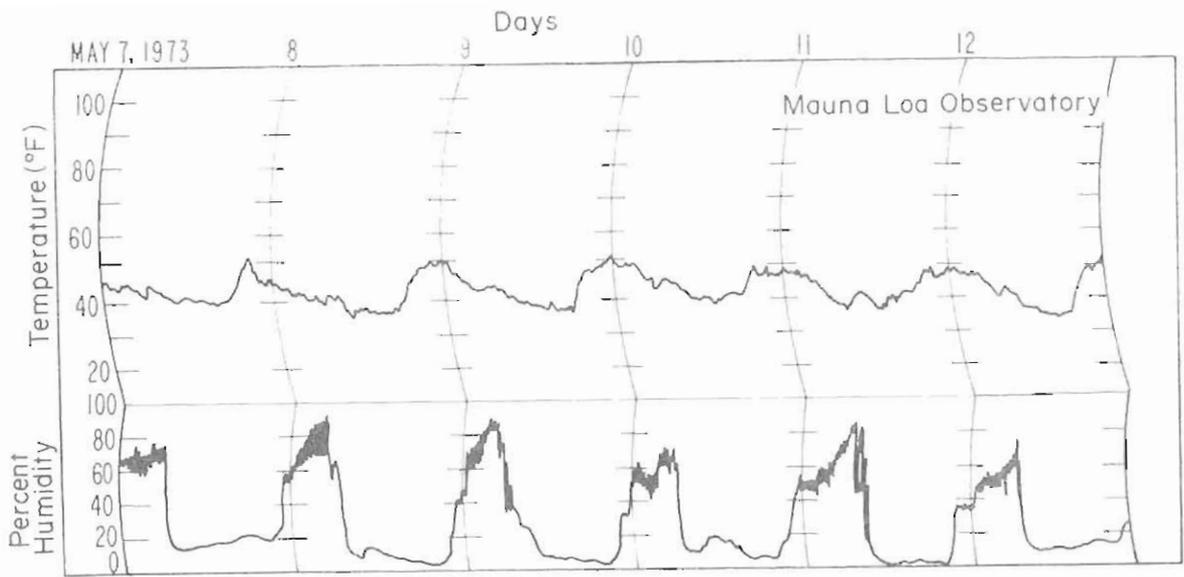
Figure 41. Example by temperature (°F) of humidity traces (percent) at MLO.

observed for each wind direction and the numbers represent percentage fre-
quency of wind observed from each direction within each speed interval.
Figure 43 shows frequency distributions for the prevailing east-southeast
winds at Matatula Point. Resultant vectors, and other monthly wind data
are listed in table 12.
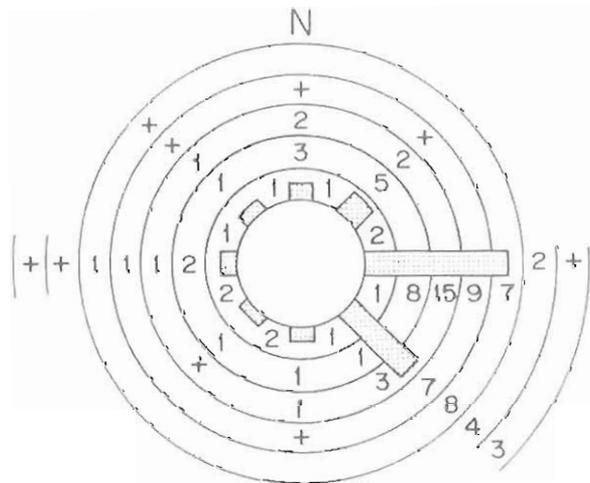
Figure 42. Surface wind' rose Cape
Matatula Jul-Dec. 1973.

N°. Of Observations = 4051

Figure 44. *Average daily air temp-erature Cape Matatula Jul-Dec. 1973.*
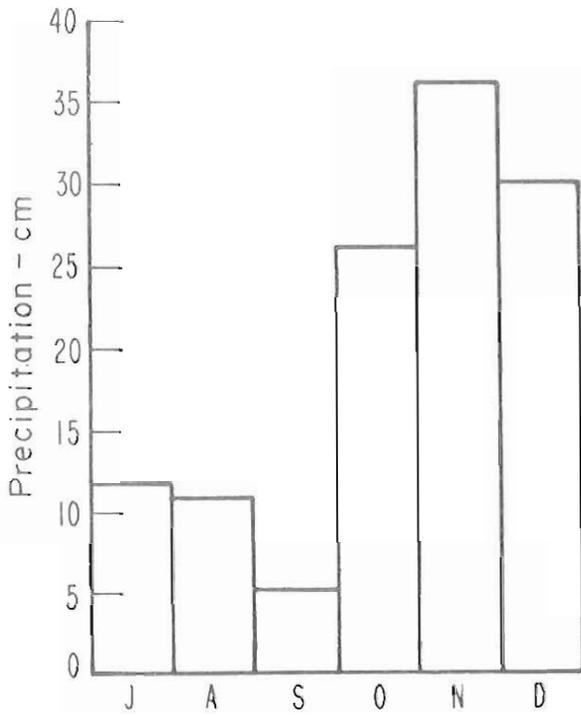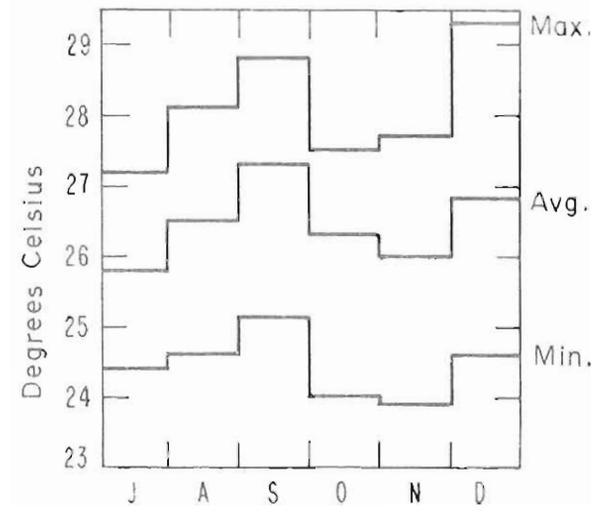
Figure 45. *Rainfall at Cape Mata-tula Jul-Dec. 1973.*

4.4 Solar Radiation

4.4.1 New Field Instrumentation

During the latter part of 1973, twenty Model 2 pyranometers were received from The Eppley Laboratories, Inc. Table 16 summarizes the properties as given by the manufacturer. Table 17 summarizes the data for the three UV radiometers that also arrived during 1973. Table 18 gives the results of some of the comparisons of the South Pole array of pyranometers to instrument 10155F4. Note the last three comparisons differ significantly from the first comparison; this suggests the possibility that the properties of 10155F4 changed suddenly, perhaps to a lower sensitivity as of December 31, 1973. Pyranometers 12268F3 through 12271F3 and UV radiometer 12349 arrived at the South Pole on January 3, 1974. The temperature response of these instruments is given in tables 19 and 20. A significant difference exists between the manufacturer's response test results and GMCC's values. The calibration technique employed by GMCC involved placing the pyranometers in the NCAR environmental chamber. Temperature was allowed to stabilize for 40 min before readings were made on a voltmeter whose calibration was traceable to NBS. The standard lamp, used as a light source, had its current monitored, and the lamp intensity was monitored by a detector outside the environmental chamber, so that the total irradiance of the lamp remained constant to within ±0.3 percent over the entire test. The manufacturer's method of testing has not been specified. Tables 21 and 22 given some further data on the UV radiometers, and table 23 gives some data on the multichannel radiometers (pyrheliometers) that arrived in late December 1973.

4.4.2 Calibration Equipment

For calibration, two Angstrom compensation pyrheliometers, two active cavity radiometers, and two primary absolute radiometers arrived in 1973. Table 24 lists the appropriate calibration constants. A McPherson double-beam recording spectrophotometer was also received. The filters to be calibrated did not arrive until very late in 1973.

Figures 46 and 47 are drawings of the detecting apertures of the Kendall radiometers. Table 25 gives some numerical data for these apertures as measured by NBS and shows that the aperture sizes do not agree with the manufacturer's claims.

4.4.3 Data Analysis

Although the data analysis was held up in 1973 by the need to standardize the raw data tapes, several analysis programs were written and tested in preparation for obtaining the standardized data tapes.

Table 19. Temperature Response Based on Manufacturer's Data for
          Pyranometers Using Sun Calibration Constant

Temp. (°C)	Serial Number				
	12268	12269	12270	12271	12272
25	0.1017	0.1025	0.0970	0.1077	0.1061
10	0.1028	0.1038	0.0981	0.1079	0.1077
-5	0.1032	0.1041	0.0983	0.1081	0.1079
-20	0.1033	0.1044	0.0985	0.1083	0.1084
-35	0.1027	0.1033	0.0975	0.1076	0.1078
-50	0.1015	0.1025	0.0965	0.1066	0.1065
	12263	12264	12265	12266	12267
30	0.0954	0.1051	0.0976	0.1061	0.0959
20	0.0955	0.1056	0.0981	0.1064	0.0964
(8)	0.0957	0.1058	0.0983	0.1068	0.0965
0	0.0958	0.1060	0.0985	0.1075	0.0966
-20	0.0955	0.1059	0.0982	0.1073	0.0964
-30	0.0946	0.1039	0.0975	0.1067	0.0958
	12273	12274	12275	12276	12277
40	0.0932	0.0966	0.0918	0.1023	0.0963
25	0.0933	0.0969	0.0917	0.1025	0.0969
10	0.0929	0.0965	0.0914	0.1025	0.0971
-5	0.0928	0.0967	0.0914	NA	NA
-10	0.0926	0.0965	0.0910	0.1019	0.0969
-20	0.0933	0.0969	0.0918	NA	NA
	12616	12617	12618	12619	12622
30	0.0790	0.0808	0.0769	0.0789	0.0938
18	0.0794	0.0812	0.0770	0.0792	0.0939
(10)	0.0794	0.0810	0.0770	0.0791	0.0940
6	0.0793	0.0809	0.0770	0.0790	0.0940
-16	0.0793	0.0809	0.0770	0.0792	0.0938
-28	0.0789	0.0807	0.0765	0.0787	0.0935

Table 20. Temperature Response of Pyranometers (South Pole Only)

Temp. (°C)	Serial Number			
	12268	12269	12270	12271
19	0.1012	0.1041	0.0956	0.1014
0	0.1028	0.1037	0.0974	0.1048
-20	0.1033	0.1044	0.0985	0.1083
-40	0.1043	0.1037	0.1080	0.1083
-60	NA	0.1019	NA	NA

Table 21. Cosine Response of UV Radiometers

Temp. (°C)	12348 (Hemisphere)	12348 (No Hemisphere)
10	1.057	1.010
20	1.030	1.007
30	1.014	1.008
40	1.005	1.010
50	1.002	1.010
60	1.000	1.000
70	0.998	0.984
80	0.981	0.982
90	0.989	0.984

Data for 12349 and 12350 not available.

Table 22. Temperature Response of UV Radiometer*

Temp (°C)	12350 (mV/mWcm^{-2})
40	1.924
25	1.906
10	1.87
-5	1.836
-20	1.810
-35	1.750
-50	1.705

*Date for 12348 and 12349 not available.

73
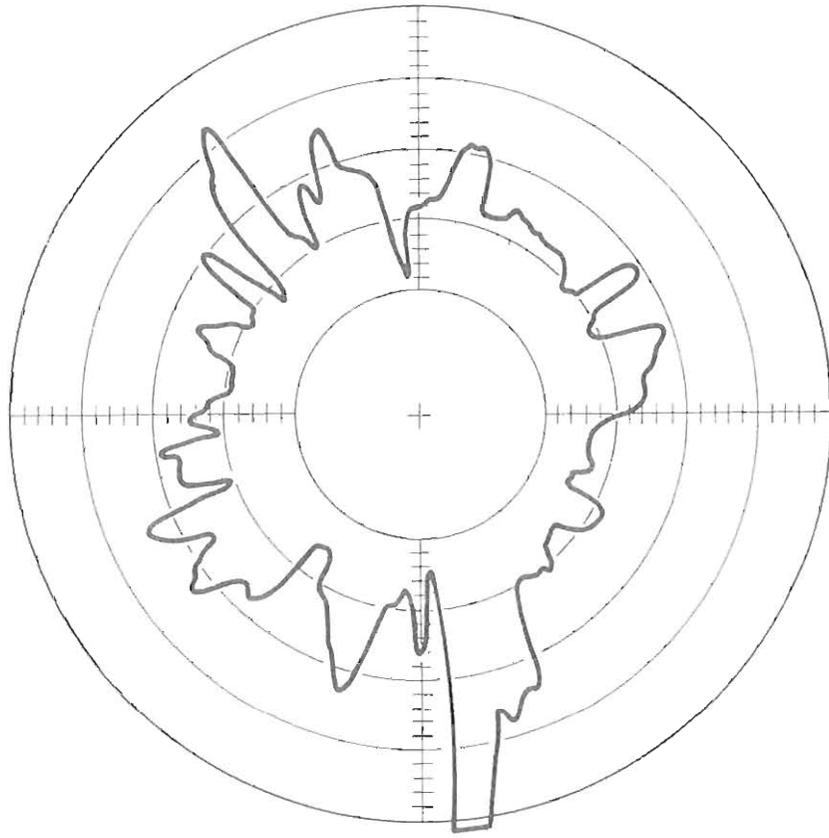
Figure 46. The deviations from roundness of the detecting aperture of the Kendall radiometer 12842 as supplied by the Eppley Laboratory, Inc. Each unit of radius corresponds to 0.001 inch.
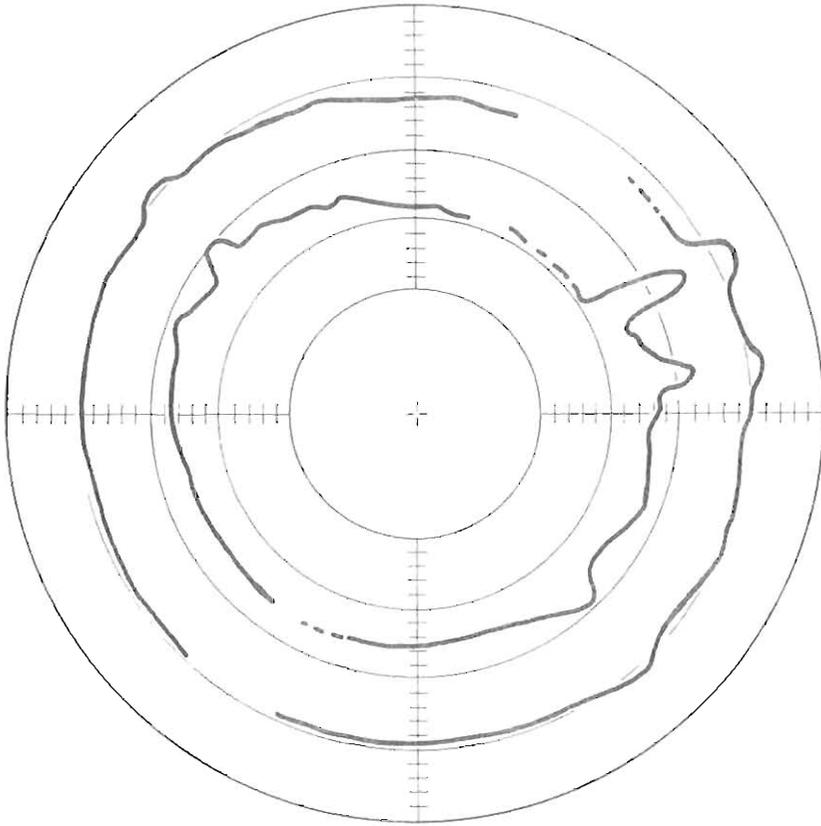
*Figure 47. The deviations of the detecting aperture of the Kendall radi-
ometer 12843 as supplied by The Eppley Laboratory, Inc. Divisions for
the outer circle correspond to 0.001 inch and for the inner circle to
0.00005 inch.*

the tape, and so forth. Averages and standard deviations are for the
printed values only. Standard deviations are large because cloudy condi-
tions are included in the calculations for the given run. All analysis
programs produce similar tables, with most of them giving daily averages
and standard deviations when applicable. The programs are constructed
so that filtering of the values is fairly easy if we wish to remove cloudy
conditions, for example.

Two plots (figs. 50 and 51) of typical days are given at Mauna Loa
for the quartz channel of the multichannel pyrheliometer. The first one
(fig. 50) is for a fairly clear day with what appears to be fractocumulus
appearing in the afternoon. The second plot (fig. 51) is a day with a
clear morning with large layered clouds appearing in the afternoon, per-
haps altostratus. Plots allow us to determine quickly what days are con-
trol days and occasionally determine the effect of clouds in the measure-
ment.

```
┌──────────────────┐
│ Input from selected │ ◄─────┐
│ data tapes.       │        │
└──────────────────┘        │
         │                   │
         ▼                   │
┌──────────────────┐    ┌──────────────────┐
│ Further selection of │◄─│ Switches to determine │
│ voltage values     │   │ values desired.    │
└──────────────────┘    └──────────────────┘
         │
         ▼
┌──────────────────┐
│ Analysis of voltage │
│ values and storage. │
└──────────────────┘
         │
         ▼
┌──────────────────┐
│ Printout of daily values, │
│ average, and standard de- │
│ viation, and monthly av- │
│ erages and standard devi- │
│ ations.           │
└──────────────────┘
         │
         ▼
┌──────────────────┐
│ Go to next month or end. │
└──────────────────┘
```
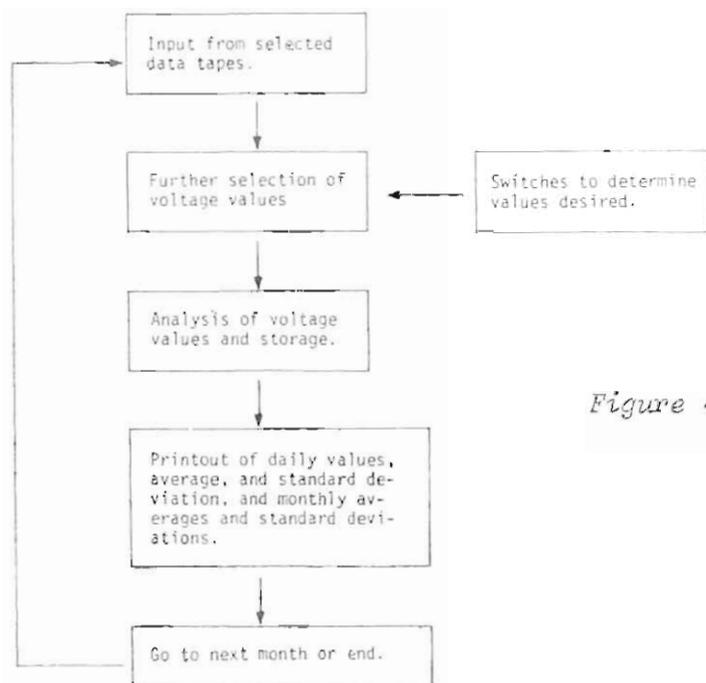
Figure 48. Typical analysis program flow chart.

4.4.4 Ultraviolet Radiation Measurements in the Erythema Spectrum

Under sponsorship of the U.S. Department of Transportation, two erythema spectrum dosimeters were developed by Komhyr (1974) at the GMCC Techniques and Standards Group, Boulder, Colorado. These instruments measure the intensity of solar ultraviolet radiation that causes sunburn and skin cancer and are intended to provide baseline information about the dependence of irradiance in the erythema spectrum on atmospheric total ozone amount, sky turbidity, and cloud conditions. The two instruments were deployed to the field stations (Bismarck, North Dakota, and Tallahassee, Florida) in June of 1973. Measurements at these sites are expected to continue until December 1974.

A unique feature of the spectrophotometer dosimeters is that their spectral sensitivity can be "tailored" to correspond to any desired erythema spectrum relative response curve. The relative response of the NOAA instruments is that shown in figure 52 which is a curve based on the data of Urback-Berger (personal communication) for wavelengths greater than 2967 Å, and data derived by Coblentz and Stair (1934) for shorter wavelengths.

Figure 53 illustrates the optical system of a spectrophotometer erythema spectrum dosimeter. Sun and sky light enter the instrument via a cosine-response light collector comprised of a slab of translucent quartz

78

SELECTED VOLTAGE OUTPUTS FOR CHANNEL NUMBER 1 IN AFTERNOON

AIR MASS =	0.5000	0.9000	1.3400	2.0100	2.6900	3.3600
DAY						
153	1.0360	4.8405	4.2171	1.8552	2.2433	0.4304
154	0.3043	0.9126	0.1577	0.0303	0.0023	-0.0037
155						
156						
157	0.3144		0.0052	-0.0075	-0.0060	-0.0062
158	-0.0014	-0.0003	-0.0044	-0.0029	-0.0028	-0.0038
159	-0.0037	-0.0031	-0.0020	0.4140	3.0632	2.6598
160	0.0005	-0.0026	0.0012	-0.0042	-0.0001	-0.0022
161	-0.0028	0.0019	-0.0033	-0.0012	-0.0034	-0.0033
162	0.0009	0.0016	0.0533	-0.0035	0.1204	-0.0037
163	-0.0030	0.0013	3.6956	3.3811	1.0813	2.4523
164						
165	6.7613	6.6378	5.0515	4.8555	4.0671	3.5566
166	0.0018	0.6759	3.5545	3.8792	2.0729	1.2325
167	6.7561	6.6379	5.2530	5.3099	4.5258	4.0117
168	3.0203	-0.0054	0.0740	4.2024	3.4639	2.9428
169	6.7195	0.2786	5.1039	0.3024	4.3151	3.8371
170	0.0103	0.3980	3.2360	4.7822	4.0454	2.1758
171	0.0127	-0.0025	-0.0040	0.0007	0.0011	2.8417
172	0.1364	4.2675	3.5978	2.6879	3.8924	3.3554
173	-0.0022	-0.0017	-0.0011	-0.0033	-0.0037	-0.0039
174		-0.0008	0.5121	0.0004	0.0039	0.2247
175	5.0948	3.9576	1.6334	1.1263	0.0329	0.0063
176	3.6339	1.0599	1.3251	0.0390	0.0154	0.4954
177	4.9350	4.0483	2.2071	3.5142	1.4150	2.2226
178	0.1644	0.2997	0.2221	0.0419	0.0173	0.0088
179	6.7239	6.5938	5.3130	2.4564	1.5273	0.6765
180	6.1897	5.3498	0.1811	0.2828	-0.0053	-0.0059
181	0.0043	3.3142	1.4075	-0.0030	0.0259	0.0049
182	0.0021	0.0039	-0.0015	1.3329	0.0034	-0.0008
AVERAGE=	1.9775	1.8947	1.3444	1.4988	1.3308	1.2290
STD.DEV.=	2.7123	2.4361	2.2639	1.8315	1.6737	1.4424

Figure 49. *The output in millivolts for the quartz channel of the multi-channel radiometer for May 1972 at MLO showing typical values for the afternoon at selected air mass values. Missing values are due primarily to tape errors and tracking errors.*
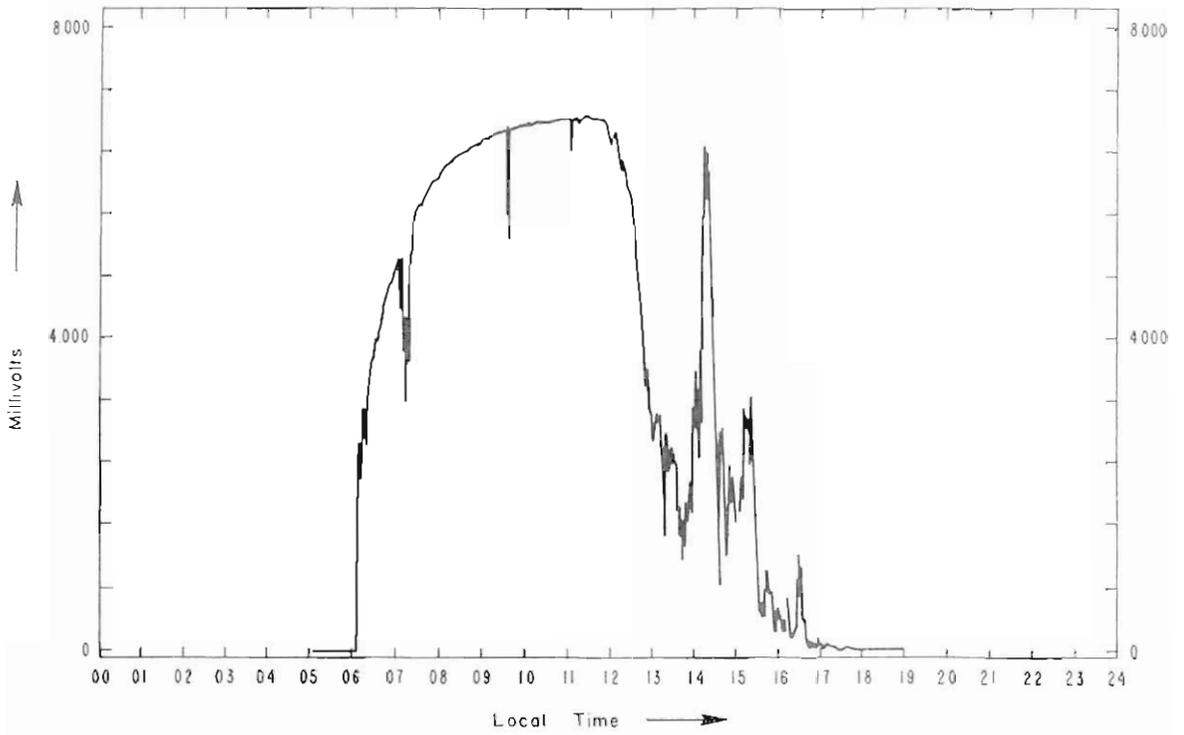
Figure 50.   Typical plot of solar radiation at MLO for quartz channel of
the multichannel pyrheliometer.
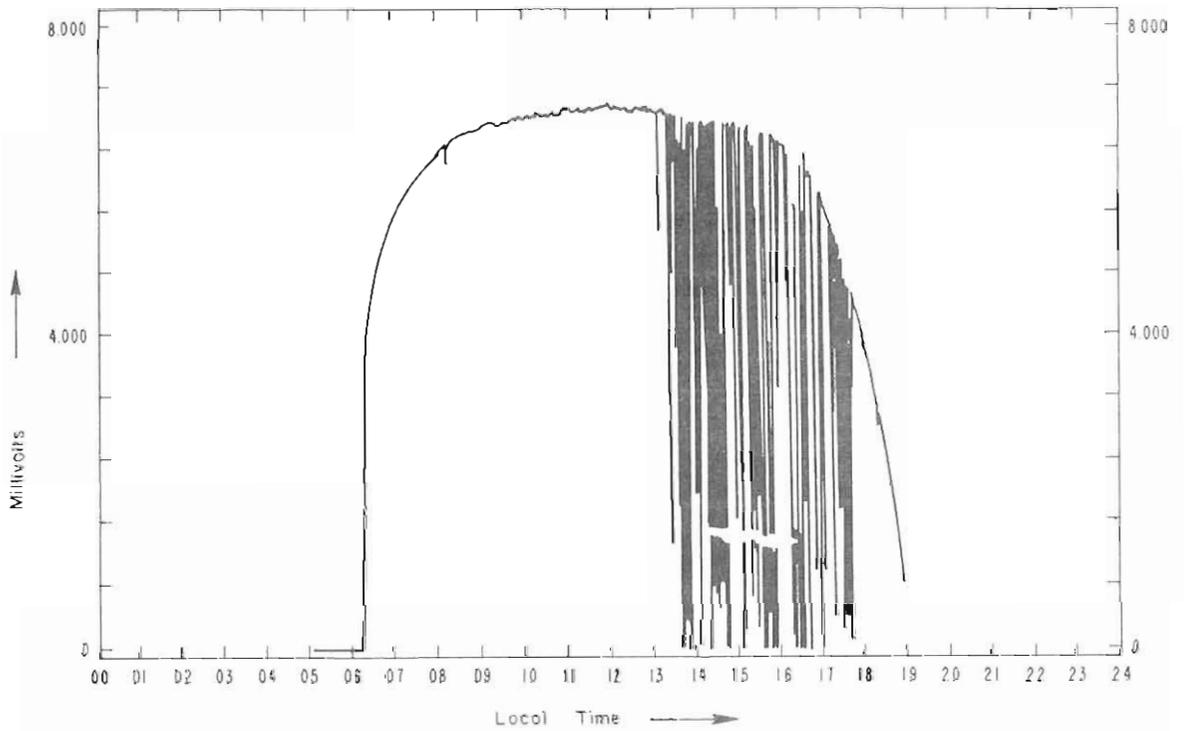
Figure 51.   Typical plot of solar radiation at MLO for quartz channel of
the multichannel pyrheliometer.

80
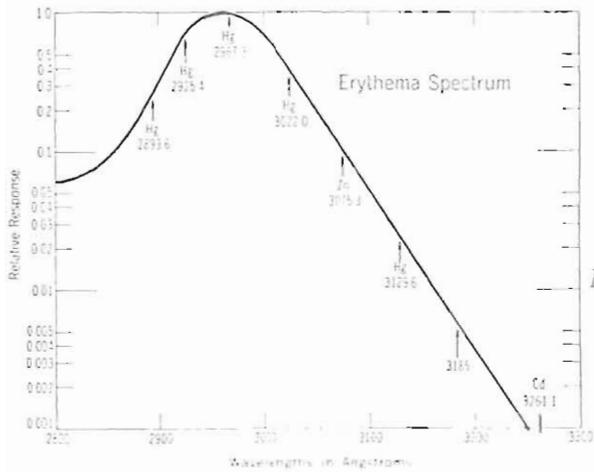
Figure 52. Action spectra for minimal erythema of the human skin.

protected from the elements by a quartz hemisphere. Beneath the light
collector is a quartz $NiSo_4 \cdot 6H_2O$-cobalt glass ultraviolet light filter
which blocks visible radiation but allows the passage of wavelengths
shorter than about 3350 Å. The ultraviolet radiation then passes
through a circular variable neutral density light attenuator, which is
automatically rotated by a feedback mechanism incident daylight inten-
sity. For the incident beam cross-section to be uniformly illuminated
as viewed by the first monochrometer, an inlet window comprised of mate-
rial similar to that of the light attenuator, but with an opposite den-
sity gradient, is positioned below the light attenuator. The light is
next reflected by a small prism into the first monochrometer of the
spectrophotometer, which forms approximately 10 Å wavelength-wide
images of the entrance slit S_1 at the instrument's focal plane; viz.,
at slit S_2 is approximately 1.5 cm wide, and the optical arrangement is
such that wavelengths falling on the slit range from 2894 Å at the
top of the slit to 3260 Å at the bottom of the slit. The focal plane
shapes the instrument's spectral response. First, a mask is fitted over
slit S_2 in such a way that the longer wavelengths are partially blocked
by the mask and are, therefore, unable to pass completely to the instru-
ment's detector, and wavelengths near the peak of the erythema spectrum
(2960 Å) pass unobstructed to the photomultiplier tube. Second, a
rotating sector wheel which chops the dispersed light beam at a frequency
of 33 Hz further attenuates longer wavelengths as compared with shorter
ones. This is accomplished by shaping the sector wheel so that wave-
lengths near 2960 Å are blocked by the shutter for one-half the period
of each shutter revolution, whereas longer wavelengths are blocked by the
shutter for times longer than one-half the period of each revolution, de-
pending on wavelength. Dispersed and suitably attenuated wavelengths are
accomplished by a second monochrometer, which also serves to minimize

81
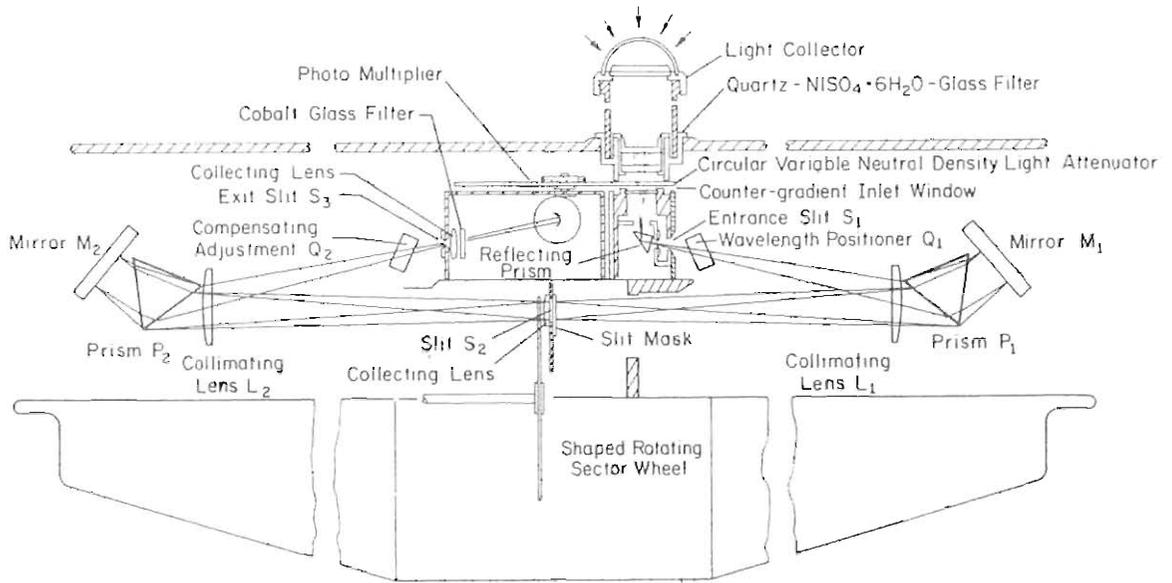
*Figure 53.   Optical system of a Dobson spectrophotometer converted
into an erythema spectrum dosimeter.*

the problems of scattered light. Additional protection against visible
scattered light is provided by a cobalt glass filter positioned behind
exit slit S_3; i.e., in front of the photomultiplier tube.

The signal emanating from the photomultiplier tube in response to
the chopped light beam is a pulsating d.c voltage that is amplified by
an a.c. amplifier and rectified by a phase-sensitive rectifier (Komhyr
and Grass, 1972) to yield a d.c. voltage level that is balanced against
a constant d.c. voltage reference source. The difference in the two d.c.
voltages (error signal) is impressed upon a servo amplifier-motor that
rotates the circular variable neutral density light attenuator in response
to changes in incident light intensity so as to maintain a constant light
level entering the instrument. Coupled to the light attenuator is a shaft
encoder that outputs information regarding the angular position of the
light attenuator disc. Through a previous calibration, the light attenua-
tor optical densities vs. angular position are known. The instrument
is absolutely calibrated through use of an Eppley Laboratory standard of
spectral radiance lamp. Thus, the U.V. erythema spectrum energy falling
on the instrument's light collector can be determined.

The observational data are recorded in digital form on an incremen-
tal tape recorder, and also in analog form on a strip-chart recorder.
Figure 54 shows typical data obtained on clear days during midsummer
and midwinter at Bismarck, North Dakota. Note that the ratio of irradi-
ance values in the erythema spectrum for the two different times of year
is approximately 15:1.

82

Figure 54. Typical plots of irradiance in the erythema spectrum measured on clear days at Bismarck, North Dakota.
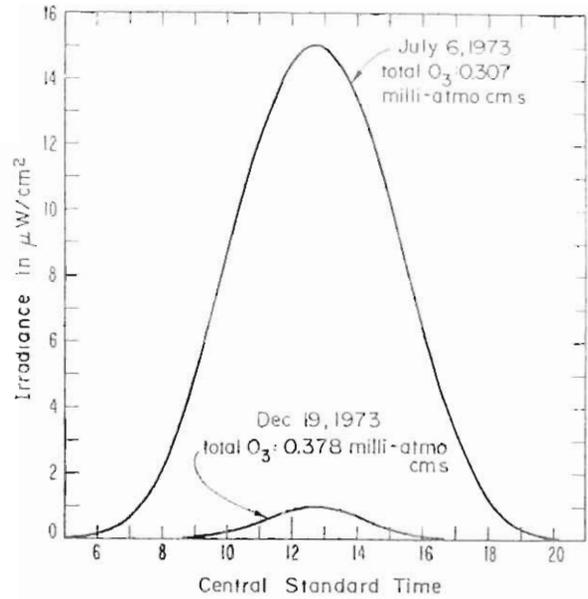
4.5 Cooperative Programs

In 1973 Mauna Loa Observatory had many cooperative programs. The active programs are: (1) Measurement of Sr^{90}, (2) Total surface particulate matter, (3) Surface tritium concentration, (4) Condensation nuclei concentration, (5) Surface SO_2 and NO_2, (6) Surface SO_2, NO, NO_2, and NH_3, (7) Precipitation collection for chemical analysis, (8) Fog concentration, (9) Atmospheric extinction, and (10) CO concentration.

The cooperative programs at Barrow, Alaska, are: (1) Smithsonian-Radiation Biology Lab's pyranometer system; (2) High volume air samples (Desert Research Laboratory, Reno, Nevada); and (3) Precipitation collection for chemical analysis.

The two cooperative programs at American Samoa are: (1) Precipitation collection for chemical analysis; and (2) NCAR surface measurement of SO_2, NO, NO_2, and NH_3.

4.5.1 Carbon Monoxide

The Mauna Loa Observatory, in cooperation with the Max Planck Institute, Mainz, Germany, has begun to measure surface carbon monoxide

83

concentrations in order to monitor daily and seasonal variations, and to establish possible trends. The system was installed by its designer, Dr. W. Seiler, on Mauna Loa in August 1973.

Method. Carbon monoxide is detected by allowing it to react with mercuric oxide at 210°C; this produces mercury vapor. The atomic absorption of mercury vapor is then measured in an optical cell; the output from the phototubes is recorded continuously by a strip chart recorder. Interfering gases are removed by drier, molecular sieves, and zero point adjustment. Calibration is done with known concentration reference gases. The detection limit of the instrument is 0.1 ppbv. The standard error for a CO mixing ratio of 0.1 ppmv is 3 percent.

System Description. The ambient air or calibration gas is pumped into the system and initially passed through cooling traps at temperatures of about -40°C. A glass tube molecular sieve eliminates interference caused by reducing gases such as SO_2, hydrocarbons, formaldehyde, and other gases that would also react with the mercuric oxide. At this point, the sample can either be passed directly into the heating module consisting of the mercuric oxide and the optical cell, or the sample can be passed first over silver oxide and then into the heating module.

Because at 210°C mercuric oxide slowly dissociates into mercury vapor and oxygen, there is a background concentration of mercury vapor passing through the optical cell depending on the flow rate. To eliminate this error source, the sample flow is automatically cycled through a carbon monoxide trap for 5 min every 50 min. The trap contains silver oxide which destroys the CO in the air sample quantitatively but does not react with hydrogen. The resulting detection level during this mode of operation is the zero point which includes the mercury level produced by thermal dissociation of HgO and the Hg-vapor generated by the reaction between H_2 and HgO. The difference between zero-point and the normal recorder reading is therefore caused only by the CO in the air sample.

The air sample now passes through the hot mercuric oxide where the CO reacts to form mercury vapor. The optical cell is within the furnace through which the air sample now containing mercury vapor passes. The air sample exits the optical cell via a flow meter and leaves the system. Flow rate is maintained at about 35 ℓ/hr.

The CO detection system (fig. 55) has a light from a mercury lamp source that traverses the optical cell and is received by a phototube at the opposite end. A second phototube observes the mercury lamp directly. The two currents from the two phototubes contain the output information. The signals are amplified and their ratio is monitored on a strip chart recorder.

Calibration. This instrument is calibrated by using cylinders of compressed air-CO mixtures. The concentration of the calibrating gases span the expected ambient air concentrations being measured. Repeatability checks for determining drift stability are also made with a tank of

84
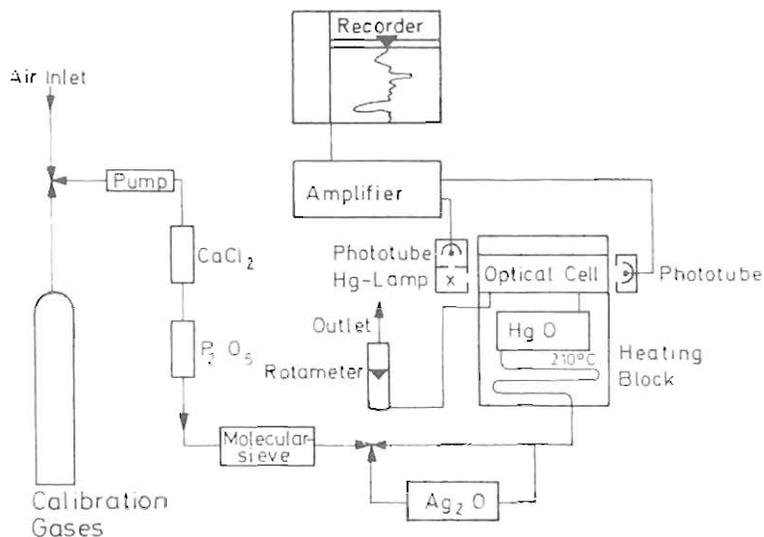
Figure 55. *Schematic diagram of the CO analyzer developed at the Max Planck Institute, Mainz, Germany. Best operational conditions are 210°C, 40ℓ/hr and 0.5g HgO* (from W. Seiler and C. Junge, J. Geophys. Res. 75, 12, 1970, copyright by American Geophys. Union).

compressed ambient air. This allows calibration runs to be made less frequently and only when needed.

Initial Operation. The shakedown period lasted throughout 1973, with numerous malfunctions occurring and many of these failures could not be immediately corrected. Few reliable data were obtained in 1973. The hope that the system would require minimum surveilance and operate unattended for extended periods has not been fulfilled.

4.5.2 *Precipitation Chemistry*

In 1973 precipitation was collected at Mauna Loa, Barrow, and Samoa for chemical analysis. In this initial program, three major problems have evolved:

1. The collector proved to be unreliable especially at the extreme conditions of the Arctic.

2. Two of the three stations (MLO and BRW) have very little precipitation (500 mm and 300 mm respectively).

3. Because of the locations of these background stations, the chemical constituents in precipitation are at very low concentrations. This requires extremely precise analyses.

Some of the MLO average yearly values of constituents are shown in table 26. During 1973, precipitation was collected only intermittantly at Barrow and Samoa.

Table 26. *Average Values of Selected Constituents in Precipitation at Mauna Loa*

Constituent	Concentration (mg/ℓ)
pH	5.90 (pH units)
SO₄	1.70
Cl	0.30
Ca	0.27
K	0.12
Mg	0.03
Na	0.78

4.6 Data Acquisition System

As part of the effort to install a reasonably complete monitoring program at the South Pole station, we completed the instrument control and data acquisition system (ICDAS) and wrote a stand-alone program for operating the system. While the operating program was written in BASIC, a set of subroutines had to be written to perform data transfer to and from peripherial devices. Such subroutines are numbered and appeared in the form "CALL N, X, Y." They were written in computer (Data General Corp., NOVA 1220) assembly language. These subroutines could transfer data files and from the magnetic tape recorder, skip files in both directions, write end-of-files, and rewind tape. The control routines for the display clock, the general purpose switches, and the teletype were modified and tested. Separate diagnostic and test routines were also produced.

The central timing program, or operating executive, was written with three tasks in mind. The first and most important was the recording of all signals on magnetic tape in real time. This recording schedule was non-interruptable. All signals, except those from the clock and switches, were acquired through a conventional multiplexer-digitizer, which was controlled by the computer. The second task was to schedule the calibration of the individual sensors through the activation of switches to set solenoid values. For the aerosol counter the switches were used to set the range of the instrument. While signals were digitized once/second and the basic observation was of 10-sec sums, the switch register was checked and updated every minute. With the ICDAS in control of the calibration of sensors, the system could be used to perform the third task, calculating hourly averages and scaling of these values in scientific units. With

86

proper guidelines, these data are used to monitor sensor performance and provide summary or climatological data. Unfortunately memory capacity will not allow the next logical step to be implemented, viz., the formulation of daily averages.

The structure of the executive program is shown in figure 56). Once a week, after the station observer changed the data tape, he initialized the program in three steps. (1) The number of analog channels to be recorded was specified, and from this the computer established the size of the data arrays. (2) Identification files were loaded into the computer via punched paper tape through a teletype reader. These files identify the station and the sensor belonging to each channel. They were logged on the data tape twice a day. (3) The start sequence simply waited for the next hour and cleared all files. The system examines the display clock waiting for the next second at which time analog data are acquired, digitized, and summed into an array. Every 10-sec a new sum starts, and at the end of each minute, during the 59th sec, the sum for that minute is tabulated, and the seven values for each channel are recorded on tape. Within each minute certain blocks of time, specific 1-sec intervals, are used to do tasks unique to individual sensors, such as, calibration scheduling and data scaling. There is plenty of time remaining after the data are digitized for such tasks as long as they are broken into sub-sections. This process is outlined in dashed lines in figure 56.

The main output of this system is on magnetic tape, recorded in a computer compatable format, at 800 bpi (bytes per inch, NRZI). The data are contained in two arrays; the signal array, $S(I,J)$, "I" representing the channel number, and

$J=0$; sums from second 0 through 9
$J=1$; sums from second 10 through 19
$J=2$; sums from second 20 through 29
$J=3$; sums from second 30 through 39
$J=4$; sums from second 40 through 49
$J=5$; sums from second 50 through 59
$J=6$; sums from second 0 through 59
$J=7$; time and switch settings.

This array is recorded once a minute. The second, the "data quality," array is where the 1 min sums are collected, it is in the form $D(I,J)$. Again "I" denotes the channel number, and

$J=0$; the sum of $S(I,6)$ for low calibration settings.
$J=1$; the sum of $S(I,6)$ for high calibration settings.
$J=2$; the sum of $S(I,6)$ for measured air values.
$J=3$; the number of data entries for low calibrations.
$J=4$; the number of data entries for high calibrations.
$J=5$; the number of data entries for measured values.
$J=6$; the calibrated average for the previous hour.
$J=7$; the value of the low calibration point.
$J=8$; the value of the high calibration point.

87

ICDAS EXECUTIVE (74)

RUN

```
┌─────────────┐
│ DIMENSION   │
│ ARRAYS      │
└─────────────┘
       │
       ▼
┌─────────────┐
│ LOAD        │
│ IDENT.      │
│ FILES       │
└─────────────┘
       │
       ▼
┌─────────────┐
│ START       │
└─────────────┘
```

```
        NEW                UNIT          YES    ┌ ─ ─ ─ ─ ─ ┐
NO ◄── SECOND ?           SEC = φ ? ──────────►   ICDAS
                                                  CONTROL    ──►
                            │ NO               │ DISLAY   │
        │ YES               ▼                  └ ─ ─ ─ ─ ─ ┘
        ▼                   UNIT          YES    ┌ ─ ─ ─ ─ ─ ┐
┌─────────────┐            SEC = 1 ? ──────────►   GECNC
│ INPUT       │                                    CONTROL   ──►
│ DATA        │             │ NO               └ ─ ─ ─ ─ ─ ┘
└─────────────┘             ▼
       │                    UNIT          YES    ┌ ─ ─ ─ ─ ─ ┐
       ▼                   SEC = 2 ? ──────────►   UNOR
┌─────────────┐                                    CONTROL   ──►
│ STORE       │             │ NO               └ ─ ─ ─ ─ ─ ┘
│ DATA        │             ▼
└─────────────┘             UNIT          YES    ┌ ─ ─ ─ ─ ─ ┐
       │                   SEC = 3 ? ──────────►   MEC
       ▼                                           CONTROL   ──►
     END OF      NO          │ NO               └ ─ ─ ─ ─ ─ ┘
    MINUTE  ──────►          ▼
       │                    UNIT          YES    ┌ ─ ─ ─ ─ ─ ┐
       │ YES               SEC = 4 ? ──────────►   S/R
       ▼                                           CONTROL   ──►
┌─────────────┐             │ NO               └ ─ ─ ─ ─ ─ ┘
│ RECORD      │
│ DATA ON     │
│ TAPE        │
└─────────────┘
```
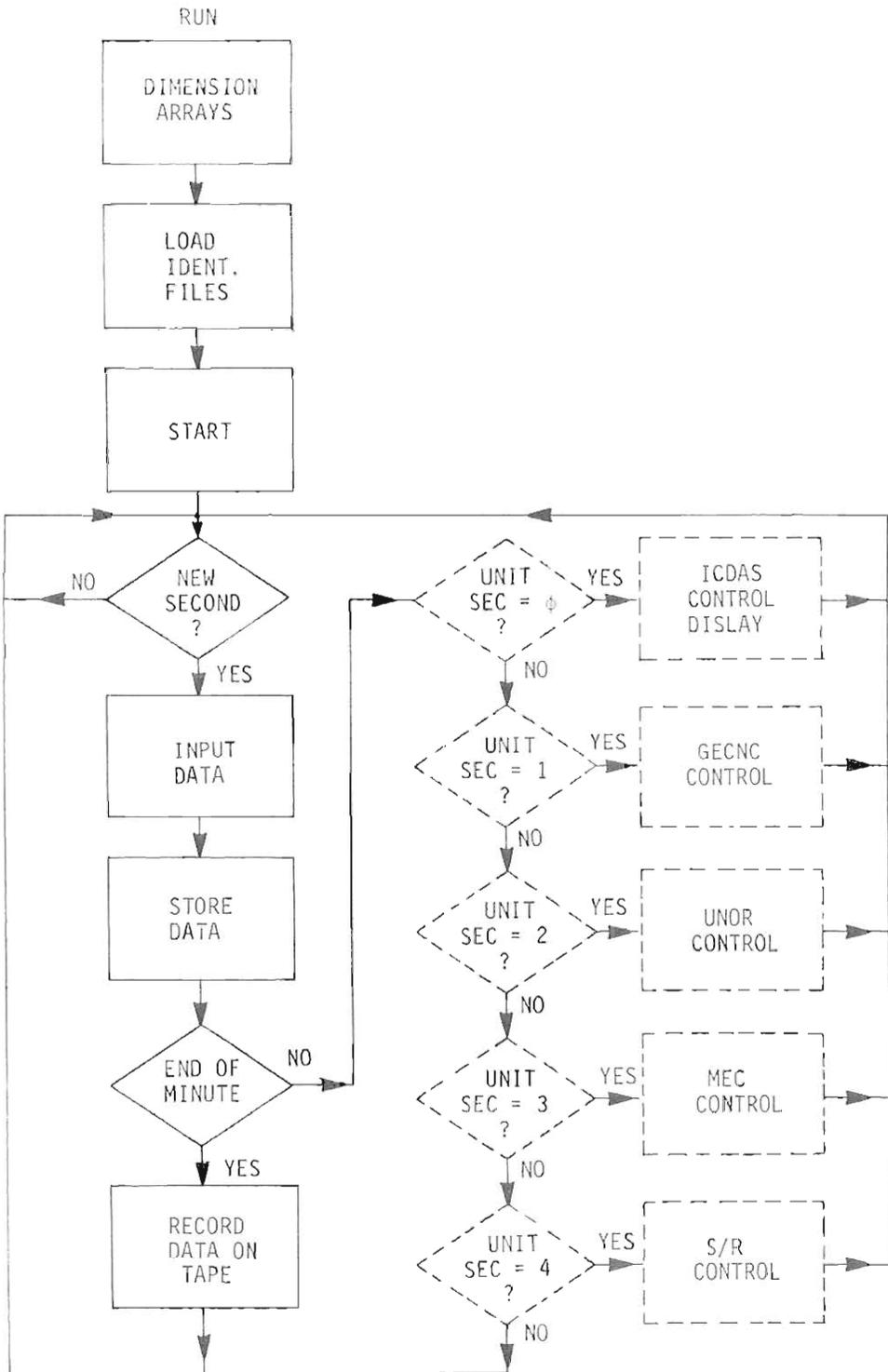
Figure 56. Flow chart of executive program.

88

This array is completed during the first minute of every hour and recorded on magnetic tape. It is followed by an end-of-file mark to allow easy access for subsequent analyses. Every 12-hours, the station identification file and channel identification file are recorded immediately preceeding the D(I,J) file.

The ICDAS hardware installed at the South Pole station is pictured in figure 57. It is housed in two equipment racks with the digital components, magnetic tape drive, and computer console, in the one on the right. The other, on the left, contains the analog components including the clock, multipoint recorder, multiplexer-digitizer, analog preamplifier, test equipment, and power supplies. Each rack contains a fan and an AC power regulator. The teleprinter with paper tape reader and punch is shown on the right.

Throughout the year, this system was tested and evaluated. In all but a few cases, the results were favorable. Thus, a request for standardization and interchangability of parts, under section 302(c) (13) of the Federal Property and Administrative Services Act of 1949, was initiated for the core of ICDAS. In this way, the new equipment for additional stations will be identical to that currently in use.

5. REGIONAL STATIONS

The 10 WMO-designated stations are a complementary network to the baseline observatories. This network was described in GMCC Summary Report No. 1 (1972). The data were published in the recent *Atmospheric Turbidity and Precipitation Chemistry Data for the World 1972.*
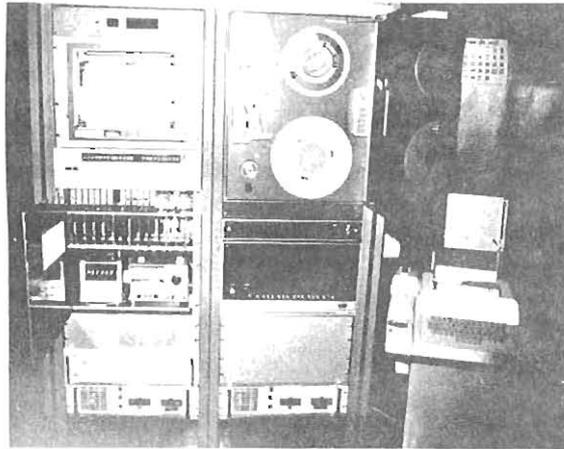
Figure 57. ICDAS hardware installed at South Pole Station.

6.   RESEARCH SUMMARY

6.1   Mauna Loa Observatory

B. G. Mendonca and R. F. Pueschel

> Ice Nuclei, Total Aerosol and Climatology at Mauna Loa, Hawaii,
> *J. Appl. Met.*, 30(1):156-160, 1973.

R. F. Pueschel, B. A. Bodhaine, and B. G. Mendonca

> The Proportions of Volatile Aerosols on the Island of Hawaii,
> *J. Appl. Met.*, 30(2):308-315, 1973.

B. G. Mendonca and G. Langer

> Ice Nucleus Counts in Varying Ambient Humidities Using an NCAR
> Ice Nucleus Counter, *J. Appl. Met.*, 30(7):1452-1454, 1973.

6.2   Geophysical Monitoring Techniques and Standards Group

W. D. Komhyr, R. D. Grass, and G. Slocum

> Total Ozone Increase Over North America During the 1960's,
> *Pure and Applied Geophysics*, 106-108(IV-VII):981-999, 1973.

L. Machta, and W. D. Komhyr

> Ozone in Aircraft Cabins, *WMO Bulletin*, XXII:222-226, 1973.

D. V. Hoyt, and G. A. Herbert

> Ground-based Measurements of Solar Radiation by Geophysical
> Monitoring for Climatic Change, *Special Environmental Report
> No. 3 Observations and Measurement of Atmospheric Pollution*,
> WMO No. 368, p. 506-515, 1973.

S. J. Oltmans

> Surface Ozone Monitors, *Special Environment Report No. 3 Ob-
> servations and Measurement of Atmospheric Pollution*, WMO No.
> 368, p. 394-403, 1973.

R. D. Grass

> Observations of Total Ozone with Dobson Spectrophotometers,
> *Special Environmental Report No. 3 Observation and Measure-
> ment of Atmospheric Pollution*, WMO No. 368, p. 413-422, 1973.

6.3 Air Resources Laboratories

D. H. Pack, R. Fegley, G. Herbert, D. Hoyt, W. Komhyr, J. Miller and C. Turner

Geophysical Monitoring for Climatic Change. The NOAA Program. *Special Environmental Report No. 3 Observations and Measurement of Atmospheric Pollution*, WMO No. 368, p. 334-345, 1973.

7. REFERENCES

Barrett, E. W., and Ben-Dov, O. (1967): Application of the Lidar to air pollution measurements, *Jour. of Appl. Met.*, 6(3):500-515.

Coblentz, W. W., and R. Stair (1934): *Data on the Spectral Erythemic Reaction of the Untanned Human Skin to Ultraviolet Radiation*, Research Paper RP631, National Bureau of Standards Journal of Research, Vol. 12, January.

Fiocco, G., and G. Grams (1964): Observations of the aerosol layer at 20 km by Optical Radar, *J. Atmos. Sci.*, 21:323-324.

Komhyr, W. D. (1974): New spectrophotometeric dosimeter for irradiance measurements in the erythema spectrum, manuscript in preparation.

Komhyr, W. D., and R. D. Grass (1972): Dobson ozone spectrophotometer modification, *Jour. App. Met.*, 11(4):858-863.

Lovelock, J. E. (1973): Halogenated hydrocarbons in and over the Atlantic, *Nature* 241:194-196.

Lovelock, J. E. (1972): Atmospheric turbidity and CCl_3F concentrations in rural southern England and southern Ireland, *Atm. Env.* 6:917-925.

Lovelock, J. E. (1971): Atmospheric fluorine compounds as indicators of air movements, *Nature* 230:379.

Lovelock, J. E., E. R. Adlor, and R. J. Maggs (1971): Gasphase caulometry by thermal electron attachment, *Anal. Chem.* 43:1962-1965.

Miller, J. M. (ed) (1973): Geophysical Monitoring for Climatic Change No. 1, Summary Report 1972, pp. 79, U.S. Dept. of Commerce NOAA.

Rosen, J. M. (1969): Stratospheric dust and its relationship to meteoric influx, *Space Science Review* 9:58-89.

Seiler, W., and C. Junge (1970): Carbon monoxide in the atmosphere, *J. Geo. Res.*, 75(12):2217-2226.

8. STAFF

8.1 Mauna Loa

8.1.1 *Directors of MLO*

Jack C. Pales, 1958-1963
Howard Ellis, 1963-1966
Lothar H. Ruhnke, 1966-1968
Howard Ellis, 1968-1970
Rudolf F. Pueschel, 1970-1972
Ronald Fegley, 1972-Present

8.1.2 *MLO Staff*

*Ronald Fegley, Director and Supervisory Physicist
*Howard Ellis, Physicist
 John F. S. Chin, Physicist
*Bernard G. Mendonca, Research Meteorologist
 Mamoru Shibata, Electronic Technician
 Alan M. Yoshinaga, Analytical Chemist
*Barry A. Bodhaine, Research Physicist
 Judith B. Pereira, Secretary

8.2 Geophysical Monitoring Techniques and Standards Group

*Walter D. Komhyr, Supervisory Physicist
*Gary A. Herbert, Research Meteorologist
*Robert Grass, Physicist
 Rudy A. Haas, Mathematician
*Thomas B. Harris, Meteorological Technician
*Douglas V. Hoyt, Physicist
 Milton S. Johnson, Electronic Technician
*Sam Oltmans, Physicist
 Colleen McAvoy, Secretary

8.3 Antarctic Observer

Russel P. Wertz, Physicist

---

*Contributors to the Summary Report.

8.4 Barrow

Daniel M. Williamson, Electronic Technician

8.5 Samoa

*Vern Rumble, Physicist

8.6 GMCC Staff

*Donald H. Pack, Director, GMCC
 Gerald F. Cotton, Statistician
*John M. Miller, Research Meteorologist
*Charles P. Turner, Technical Assistant to the Director
*James A. Watkins, Lt. (jg.) NOAA Corps

---

*Contributors to the Summary Report.

APPENDIX A: Data Taken At Observatories

(1) Gases

    (a) CO_2 (MLO, BRW, SMO, SP)
    (b) CO (MLO)
    (c) Total O_3 (MLO, BRW, SP)
    (d) Sfc O_3 (MLO, BRW, SMO, SP)
    (e) Freon (MLO, BRW, SMO, SP)
    (f) SO_2, NO, NO_2, NH_3 (10 and 24 hr sample each 2 weeks) (MLO, SMO)
    (g) SO_2, NO_2 (48 hr avg. weekly) (MLO)
    (h) HT, HTO (MLO)

(2) Meteorological

    (a) Wind speed and direction (MLO, BRW, SMO, SP)
    (b) Temperature and dew point (MLO, BRW, SMO, SP)
    (c) Pressure (MLO, BRW, SMO, SP)
    (d) Precipitation (MLO, BRW, SMO, SP)
    (e) Ground temperature (MLO)
    (f) Cloud cover (BRW, SMO)
    (g) Snow cover (BRW)

(3) Aerosols

    (a) Lidar (MLO)
    (b) Aitken nuclei concentration (MLO, BRW, SMO, SP)
    (c) Total surface particulate matter (MLO, SMO)
    (d) Particle counter (MLO)

(4) Solar terrestrial radiation

    (a) Direct solar spectral irradiance (MLO)
    (b) Global solar spectral irradiance (MLO, BRW)
    (c) Atmospheric turbidity extinction coefficient (MLO, BRW, SMO)

(5) Miscellaneous

    (a) Precipitation chemistry (MLO, BRW, SMO)
    (b) Sr^{90} in rain (MLO)
    (c) Fog concentration (MLO)

MLO = Mauna Loa Observatory
BRW = Barrow, Alaska
SMO = American Samoa
SP = South Pole

APPENDIX B: Master Manuals File — Instructions

To preserve for posterity a record of the manner in which operations are and will be conducted at our GMCC Observatories, we have established a *Master File of Instruction and Instrument Manuals* under the categories:

1.   Aerosol Monitoring
2.   Aerosol and Gas Sampling Systems
3.   Analyzer CO_2 Measurements
4. CO_2 Flask Sampling
5.   Data Acquisition/Instrumentation Control Systems
6.   Freon-11 (CCl_3F) Sampling
7. H_2O Freezers
8.   Total Ozone Observations
9.   Surface Ozone Monitoring
10.   Ozonesonde Observations
11.   Oxygen Flask Sampling
12.   Solar Radiation Observations
13.   Turbidity Measurements
14.   Precipitation Measurements
15.   Wind Observations
16.   Temperature Measurements
17.   Test and Laboratory Equipment Manuals
18.   Message Format — Special Instructions
19.   Station/Program Reports
20.   Provision is made under items 20 to 30 to record new manual categories as they become established.

Included in the Master Manuals File are (a) a *Manuals Record Book* listing all the manuals in the master file, and (b) a *Card Index* listing all manuals and for checking manuals out of the master file; e.g., for temporary use. The Master Manuals File also contains manuals relevant to the GMCC work but prepared before the establishment of the GMCC program. These include instructions pertaining to surface ozone measurements, ozonesonde observations, oxygen flask sampling, etc.

The Master Manuals File is maintained by the Chief, GMCC Techniques and Standards Group, Boulder, Colorado, who is also responsible for periodic updating of the file. A identical file is maintained at the GMCC Central Office, ARL, Silver Spring, Maryland.

1.   Aerosol Monitoring

1.   Preliminary Instructions for Small-Particle Detector Type CN, Serial No. 1098, with Calibration Curve, Gardner Associates, Inc.

2.   Instruction Manual — Condensation Nuclei Counter Catalogue No. 112L 428G1, G2, G3, G4, Rev. 2, GEI No. 45069, September 1972.

3. Instruction Manual — Pre-humidifier for Use with the G.E. Condensation Nuclei Counter.

2. Aerosol and Gas Sampling Systems

1. Instruction Manual — Aerosol and Gas Sampling System (for use at South Pole Station), prepared January 2, 1974, by W. D. Komhyr.

3. Analyzer CO_2 Measurements

1. Instruction Manual — CO_2 Measurements with a Non-dispersive Infrared Analyzer, prepared by W. D. Komhyr and T. B. Harris, Jan. 2, 1974.

2. Servicing Instructions for UNOR Gas Analyzers, No. 1390/157.

3. Instruction Manual for ACR Series Silicon Controlled Rectifier A.C. Regulators, Raytheon Company.

4. Instruction Book — Model 200 LIRA Infrared Analyzers, Mines Safety Appliance Co., June 1960.

5. URAS 1 Infrared Gas Analyzer (operating manual), Intertech Corporation, received June 1973.

6. Instructions for URAS-2 Infrared Gas Analyzer — Carbon Dioxide, Serial No. 37626682, Intertech Corporation, August 17, 1973.

7. Operating Manual 42CG57-3en, URAS 2 Infrared Gas Analyzer, Intertech Corporation.

8. Operating and Service Manual — Strip Chart Recorders 7100B/7101B/7127A/7128A, Hewlett-Packard.

9. Operating and Service Manual — 17500 A Multiple Span Input Module, Hewlett-Packard.

4. CO_2 Flask Sampling

1. Carbon Dioxide Flask Sampling Program — Instruction Manual, prepared 15 February 1967 by T. B. Harris.

2. Instructions for Taking Air Samples on Board Ship — Carbon Dioxide Program, prepared August 1968, by T. B. Harris.

3. Preliminary Report — Flask Sample Analysis Equipment for CO_2, prepared December 1967 by W. Bischof.

5. Data Acquisition/Instrumentation Control Systems

Synopsis of Support Material (printed) for
Instrumentation Control and Data Acquisition System

Overall

Manuals containing operation, maintenance, and repair information for
each component of the ICDAS are provided by the manufacturer. A component
is defined by a certain area of rack space; therefore the manuals are as-
sembled into binders representing a single rack. Using the South Pole
deployment as an example, all hardware components are contained in bind-
ers labeled "analog rack," "digital rack," and "teletype." Software is
handled in a different way. Three systems tapes are provided to house
the "diagnostics," "system generating routines (assembly language)," and
"executive generating routines (basic)." A binder containing the operat-
ing instructions and code listing is provided for each type. The indi-
vidual manuals within each binder are listed below.

Hardware

Analog Rack (top to bottom)

Multipoint Recorder (Leeds and Northrup Co). This recorder is
supported by a maintenance and operation manual as well as a parts manual.

Multiplexer-Digitizer (Xerox Data Systems). Two manuals are en-
closed, one for the MUX-Digitizer operation and one for the power supply.

Preamplifiers (Newport Labs., Inc.) The manual contains test
instruction as well as schematics.

Switch Registers. This unit was built by T&SG and the manual
contains board layout, parts location, and pin assignments.

Power Supplies (Hewlett-Packard, Inc.) One manual is provided
for each class of power supply.

AC Line Regulator (Elgar Co.) One manual is required for this
unit and a companion unit in the digital rack.

Digital Rack (top to bottom)

Magnetic Tape Drive (Wangco, Inc.) The material for this sys-
tem is in two locations. All hardware description, maintenance, and op-
eration instructions are located in the manual. The definition of the
tape format is contained in "How to Use the NOVA" book.

Magnetic Tape Formatter (Data General Corp.) The material for this interface unit is included with the material for the tape interface board in the following section.

Minicomputer (Data General Corp.) Following the descriptive material and diagrams for the mainframe and the console, the details for each subassembly or pc board are filed. Operating and interfacing instructions are contained in a second, separate volume entitled "How to Use the NOVA." Material for the display clock is contained in this location.

Teleprinter, Reader, and Punch (Teletype). Due to their size, these manuals require a separate binder.

Software

System Reliability and Diagnostics. This binder contains manuals in support of each reliability program and diagnostic routine. The former are used to generate timing tables for the central processing unit and the magnetic tape transport. Diagnostic routines are used to locate malfunctions.

System Generating Programs (Assembly Language). The corresponding tape contains the minimum number of programs required to write and assemble machine language code.

> Paper tape editor (DGC tape 91-1-7)
> Assembler (DGC tape 91-2-8)
> Basic with Call Subroutines (Hall)
> Basic with Call Subroutines Ver. 4.4.-C

The manual also contains programming instructions for assembly language and machine language code.

Assembly language listing of Basic w-call

Executive Generating Routines (Basic)

The corresponding tape contains the final operating executive and special test routines.

> Basic 4.4-C, South Pole Executive
> Basic 4.4-C, Statistics routine (1-hour version)
> Basic 4.4-C, Statistics routine (10-min version)

6. Freon-11 (CCl₃F) Sampling

1. GMCC Program — Freon-11 (CCl_3F) Sampling, Instructions from ARL Fro, Idaho Falls, dated 9/5/73.

7. H₂O Freezers

1. Operating Instructions — General Technical Data, Cincinnati Sub-Zero Products, Inc.

2. CC-100f Instruction Manual, Neslab Instruments, Inc.

3. Instruction Manual — Cryocool CC-100f Freezer and Trap Unit (for use at South Pole, Antarctica, with the CO_2Analyzer), prepared by W. D. Komhyr, January 2, 1974.

8. Total Ozone Observations

1. Dobson Spectrophotometer
   Beck, London, prepared by G.M.B. Dobson on behalf of the I.O.C.

2. Adjustment and Calibration of Ozone Spectrophotometer
   Revised January 1956, R&J Beck, Limited.

3. Observers' Manual — Dobson Ozone Spectrophotometer
   (Comprehensive Program of Observations) prepared September 1, 1962 by W. D. Komhyr.

4. Observers' Manual — Dobson Ozone Spectrophotometer
   (Limited Program of Observations) prepared July 1, 1963, by W. D. Komhyr.

5. Observers' Manual — Dobson Ozone Sepctrophotometer
   (Limited Program of Observations) revised November 1, 1972, by W. D. Komhyr and R. D. Grass.

9. Surface Ozone Monitoring

Manuals listed in 1 through 16 deal with instruments used before GMCC.

1. Instruction Manual for Operators of the Regener Automatic Surface Ozone Recorder (Antarctica Stations September 1962-September 1963) prepared by W. D. Komhyr.

2. Technical Manual Automatic Ozone Recorder, October 30, 1956 University of New Mexico, Department of Physics.

3. Technical Manual Modified Automatic Ozone Recorder, August 18, 1960. University of New Mexico, Department of Physics.

4. Instruction Manual for Operators of Mast Model 724-1 or 724-2 Surface Ozone Meters (Antarctica Stations, September 1962-September 1963) prepared by W. D. Komhyr.

5. Operation and Maintenance Manual — Ozone Meter MDC Model 724-1, prepared by Mast Development Co., Davenport, Iowa.

6. Operation and Maintenance Manual — Mast Model 724-2 Ozone Meter, prepared by Mast Development Co., Davenport, Iowa.

7. Technical Information — Model G-11A Strip Chart Recorder, Varian Associates, Palo Alto, California.

8. Instruction Manual for Operators of the Regener Chemiluminescent Surface Ozone Recorder (Antarctica Stations, September 1962-September 1963) prepared by W. D. Komhyr.

9. Technical Manual — Regener Chemiluminescent Surface Ozone Recorder University of New Mexico, Department of Physics (not available).

10. Instruction Manual for Operators of Mast Model 724-1 or 724-2 Surface Ozone Meters (Antarctica Stations, September 1963-September 1964) prepared by W. D. Komhyr.

11. Instruction Manual for Operators of the Regener Chemiluminescent Surface Ozone Recorder (Antarctica Stations, September 1963-September 1967) prepared by W. D. Komhyr.

12. Instruction Manual for Operators of Mast Model 724-1 and 724-2 Surface Ozone Meters (Antarctica Stations, September 1964-September 1967) prepared by W. D. Komhyr.

13. Instruction Manual — Carbon-Iodine Oxidant Meters Models CIO-SR and CIO-SSR, prepared by W. D. Komhyr.

14. Instruction Manual ECC Oxidant Meters Model 002 (revised August 1, 1969) Astro Engineering, Boulder, Colorado 80302.

15. Instruction Manual for Operators of ECC Oxidant Meters Model 002 (October 1972) prepared by R. D. Grass.

16. Instruction Manual ECC Oxidant Meter Model 002 (revised April 1, 1972) Astro Engineering, Boulder, Colorado 80302.

The following manuals are for equipment currently in use:

17. Surface Ozone Monitoring, prepared by S. J. Oltmans, September 1, 1973.

18. Surface Ozone Monitoring (South Pole Station) prepared by S. J. Olt-
    mans, September 1, 1973 (revised January 1974).

19. Instruction Manual, ECC Oxidant Meter Model 001 (December 1, 1968)
    Astro Engineering, Boulder, Colorado 80302.

20. Instruction Manual for MEC Series 1100 Ozone Meters (December 1972)
    McMillan Electronics Corp., Houston, Texas 77036.

21. Instruction Manual for MEC Series 1000 Ozone Generators (September
    1971) McMillan Electronics Corp., Houston, Texas 77036.

22. Instruction Manual, Ozone Generator Series C-07-10 (January 10, 1964)
    University of New Mexico, V. H. Regener, Albuquerque, N.M.

23. D.C. Recorder Manual (1969) Rustrak Instrument Division, Gulton In-
    dustries, Inc., Manchester, N.H. 03103.

24. Strip Chart Recorders 7100B/7101B/7127A/7128A, Hewlett-Packard, San
    Diego, California 92127 (1971).

25. Operating and Service Manual, 17501A, 1MV, Multiple Span Input Mod-
    ule, Hewlett-Packard, San Diego, California 92127 (March 1969).

10.   Ozonesonde Observations

1. Chemiluminescent Ozonesonde Type T9 — Description and Instructions
   No. 0110, September 23, 1963, prepared by V. H. Regener, University
   of New Mexico.

2. Chemiluminescent Ozonesonde Type T9/T11 — Description and Instruc-
   tions No. 0110, September 23, 1963, prepared by V. H. Regener, Un-
   iversity of New Mexico.

3. Instruction Manual — Antarctic Ozonesonde Program (Regener Chemi-
   luminescent Ozonesondes), U.S. Dept. of Commerce, October 1, 1963,
   prepared by W. D. Komhyr.

4. Instruction Manual — Antarctic Ozonesonde Program (Regener Chemi-
   luminescent Ozonesondes), October 1, 1964, U.S. Dept. of Commerce,
   prepared by W. D. Komhyr.

5. Instruction Manual — IQSY Ozonesonde Program (Regener Chemilumines-
   cent Ozonesondes), October 15, 1964, U.S. Dept. of Commerce, pre-
   pared by W. D. Komhyr.

6. Flight Preparation Instructions for the Mast Model 730-5 Ozone Sensor, January 7, 1964, Mast Development Company, prepared by James I. Mueller.

7. Instruction Manual — Carbon Iodine Ozonesonde Model CI-1A, October 1, 1965, ESSA, prepared by W. D. Komhyr.

8. Instruction Manual — Carbon Iodine Ozonesonde Model CI-1A (1680 Hz WB Radiosonde), October 1, 1965/revised January 3, 1965, ESSA, prepared by W. D. Komhyr.

9. Instruction Manual — Carbon Iodine Ozonesonde Model CI-1A (for use with 1680 Hz WB Radiosonde), November 1, 1967, prepared by Science Pump Corporation, Camden, N.J.

10. Instruction Manual — Carbon Iodine Ozonesonde Model CI-1B (1680 Hz AF Radiosonde), November 1, 1967, prepared by Science Pump Corporation, Camden, N.J.

11. Instruction Manual — Electrochemical Concentration Cell Ozonesonce Model ECC-1A (For use with 1680 Hz WB Radiosonde), October 1, 1968, prepared by Science Pump Corporation, Camden, N.J.

12. Instruction Manual — Electrochemical Concentration Cell Ozonesonde Model ECC-1A (For use with 1680 Hz WB Radiosonde), October 1, 1968/revised January 1, 1970, ESSA, prepared by W. D. Komhyr.

11. Oxygen Flask Sampling

1. Instruction Manual — Air Sampling with Stainless Steel Flasks (Oceanographer Cruise, April-December 1967), prepared March 20, 1967 by W. D. Komhyr.

12. Solar Radiation Observations

1. Instrument Manual and Operating Instructions for the Solar Irradiance Measurement System. November 1969, revised June 16, 1971. Prepared by The Eppley Laboratory, Inc., for Mauna Loa Observatory.

2. Construction and Operation of the Angstrom Compensation Pyrheliometer. December 13, 1972. Prepared by Douglas V. Hoyt, GMCC.

3. The Eppley-Angstrom Compensation Pyrheliometer and Associated D.C. Electrical Instrumentation. Prepared by The Eppley Laboratory, Inc.

4. Instruction Manual, Eppley-Kendall Absolute Radiometer, Pacrad. August 5, 1971. Prepared by The Eppley Laboratory, Inc.

5. South Pole Pyranometer Instruction Manual. December 1973. Prepared by Douglas V. Hoyt, GMCC.

6. Operating Instructions for Model RS-10. December 11, 1968. Prepared by McPherson Instrument Co.

7. Strip Chart Recorders 7100B/7101B/7127A/7128A. March 1971. Prepared by Hewlett-Packard.

8. Single Span Input Module 1750A. September 1968. Prepared by Hewlett-Packard.

9. Wiring Schematics for Model 783. December 5, 1971. Prepared by McPherson Instrument Co.

10. Model 783 Lock-in Amplifier. Prepared by McPherson Instrument Co.

11. Multichannel Radiometer. March 1974. Prepared by The Eppley Laboratory, Inc.

12. Sunphotometer Instruction Manual. Prepared by Environmental Protection Agency and The Eppley Laboratory, Inc.

13. Turbidity Measurements

1. Atmospheric Turbidity Program — Instructions for Using the DA Model Sunphotometer.

14. Precipitation Measurements

Manuals to be supplied at a later date.

15. Wind Observations

Manuals to be supplied at a later date.

16. Temperature Measurements

Manuals to be supplied at a later date.

17. Test and Laboratory Equipment Manuals

1. Modular Power Supplies A, C, and E Series, Models 62003A-62048A, 62003C-62048C, and 62003E-62048E. Operating and Service Manual for Serials 1210A-00101 and above. Hewlett-Packard, May 1972.

18. Message Formats — Special Instructions

1. Message Format and Data Handling Instructions (South Pole Station), prepared January 2, 1974, by D. H. Pack and W. D. Komhyr.

19. Station/Program Reports

1. Regener Chemiluminescent Surface O_3 Report, South Pole, November 1962-November 1963, by Craig Brown and Ken Jensen.