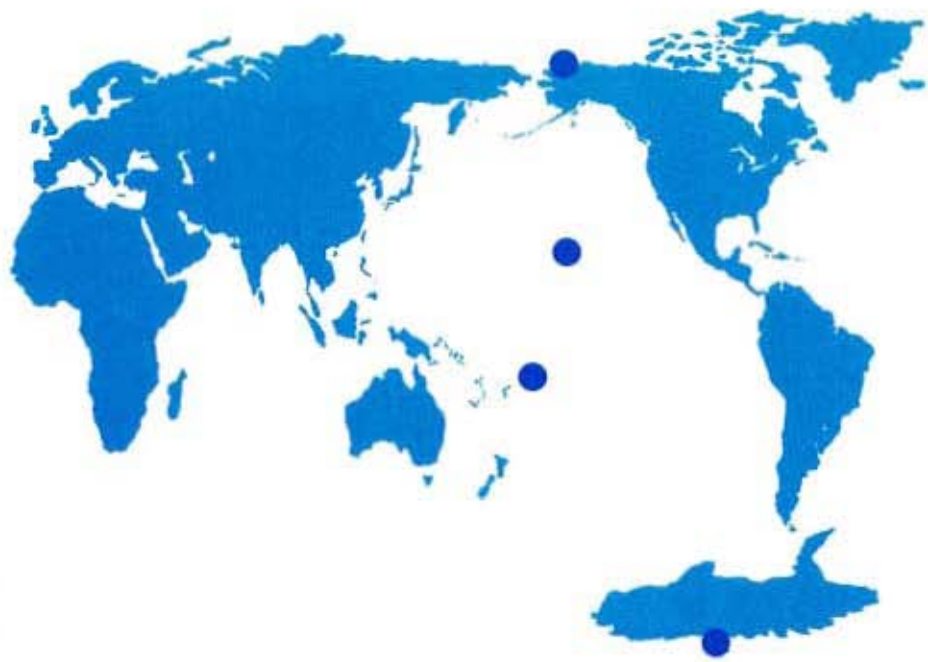
Geophysical Monitoring for Climatic Change

No. 1

Summary Report 1972



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LABORATORIES

U.S. DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator
ENVIRONMENTAL RESEARCH LABORATORIES
Wilmot N. Hess, Director

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE NO. 1 SUMMARY REPORT - 1972

John M. Miller, Editor

Contributors

Barry A. Bodhaine
Ronald Fegley
Robert Grass
Thomas B. Harris
Gary A. Herbert
Douglas V. Hoyt
Walter D. Komhyr
Bernard G. Mendonca
Sam Oltmans
Donald H. Pack
Charles P. Turner

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FOREWORD

The documentation and preservation of observational data has a special place in science. Chinese astronomers recording the passage of Halley's comet in 1400 B.C. provided a baseline observation still valuable today.

In meteorology the length of quantitative record is relatively short with the first measurements beginning in the mid-1600's with the invention of the barometer and thermometer. Organized global coverage only comprises data for perhaps a hundred years. Through ingenious studies of glaciers, pollen, tree rings, sea sediments and vintner's records the general character of the weather has been synthesized into climate, and the outlines of the changing patterns extended back over many millennia. However, the causes for the cycles of warming and cooling, drouth, and increased precipitation are still unknown. Speculation on the causes range from solar changes to tectonic activity and include effects due to the variations in the gaseous and aerosol composition of the atmosphere.

Now we have the added factor of man's technology reaching levels where effects can be detected on a global scale, as witnessed by the slowly increasing level of carbon dioxide produced by fossil fuel combustion.

As late as 1951, H. Cauer could say in the *Compendium of Meteorology*: "Although a good basis for chemical investigations of the atmosphere was established during the past century...a full incorporation of chemical concepts and procedures into the consideration of meteorological phenomena has not, up to the present, become general." Thus our documentation of atmospheric trace constituents is both sparse and brief, which is especially true for continuous records unaffected by the nearby works of man. This situation has begun to change, and in the last 10 to 15 years there have been many new studies of the geochemistry of the earth-ocean-air system.

The National Oceanic and Atmospheric Administration's program "Geophysical Monitoring for Climatic Change" is a part of this increased interest and is designed to establish and maintain a program of observation and analysis of data representative of the global background of selected gases and aerosols. This report, the first in an annual series, will document the progress of this effort. Comments and suggestions by which we can improve the usefulness of these reports will be welcome.

Wilmot N. Hess, Director
Environmental Research Laboratories
National Oceanic & Atmospheric
Administration

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE
Summary Report 1972

Air Resources Laboratory

1. INTRODUCTION

The first Summary Report of the Program "Geophysical Monitoring for Climatic Change (GMCC)" has as its genesis the unknown observer of antiquity who, realizing that an observation unrecorded was an observation lost, inscribed a record on stone or clay. The GMCC program coalesced from a variety of efforts and was given impetus by the increasing realization of the quickening of environmental change. In his message sending the First Annual Report of the Council on Environmental Quality to the Congress in August 1970, President Nixon said in part:

> "In dealing with the environment we must learn not how to master nature but how to master ourselves, our institutions, and our technology. We must achieve a new awareness of our dependence on our surroundings and on the natural systems which support all life, but awareness must be coupled with a full realization of our enormous capability to alter these surroundings."

It is the objective of the GMCC program to respond to the need for this new awareness by providing a portion of the quantitative description and analysis needed. Specifically, it is our objective to measure the necessary parameters for establishing trends of trace constituents important to climate change and of those elements that can assist in apportioning the source of changes to natural or anthropogenic sources, or both. This program has its special focus in establishing a long-term time series from ground-based instrumentation. The reason being that the sensitivity needed to determine trends in atmospheric composition within a short time span — tens of years — can only be economically and adequately accomplished by ground-based equipment using the current state of measuring techniques. We are not reporting on the interesting and essential measurements made by other groups, particularly those in the stratosphere. The program uses instrumentation whose characteristics are either well known or can be determined with considerable accuracy. New instrumentation will be tested and introduced when it meets these criteria and when it provides more accurate and useful information.

In this first report it is appropriate to explain the philosophy and structure of the program. The data are collected by a few observatories whose location was, or will be, chosen to sample representative latitudes within both hemispheres — polar, mid-latitude, and tropical. Specific sites are selected where local man-made or biota interferences are minimal. Finally, the observatories are placed where logistics and personnel can be maintained at reasonable costs.

First priority is placed on the collection of impeccable measurements of trace constituents. This effort is supported by a Techniques and Standards Group, which has the responsibility of (1) acquiring or designing and assembling equipment to meet precise criteria required, (2) developing and maintaining uniform instructions and necessary methods of measurement, and (3) maintaining calibrations that serve both to interconnect the widely separated stations and to achieve the best absolute values possible. In addition, data collecting and handling is strongly oriented towards computer techniques for data processing and automated quality control. Research on new methods and the local variability of trace materials is included in the program. Program direction, data analysis, and operational assistance are centered in the Program Director's Office.

This report and the subsequent issues will serve several purposes. The first is to establish a readily available history of the physical characteristics of the locations where "background," baseline," or "clean air" (the nomenclature is not yet universal) measurements are made by the GMCC. The descriptions will include maps, sketches, photographs, and where possible satellite-derived views of the observatories and their environs as well as written material. We hope that this material will permit determination of local and regional changes in land use, which might affect the data, and assist in reconstructing observatory history.

The report will also include an inventory of the measurements made and identify, in as much detail as necessary, the instrumentation used. Such elements as instrument serial numbers, dates of calibration, and installation of new instruments will be included.

We also plan to describe, or reference, any special observation or data reduction methods. We can anticipate that research and technology will improve and change techniques. We wish to make it feasible for our successors to reproduce our methods.

Brief summaries of research done within the program together with literature citations will be included for the interested reader.

This report covers four locations at which measurements are now in progress: Mauna Loa, Hawaii; Amundsen-Scott Station (South Pole), Antarctica; Point Barrow, Alaska; and Tutuila Island, American Samoa. Mauna Loa has the longest history, some observations started in 1951, but measurements of data more properly began in 1956 with measurements of carbon dioxide (CO_2), solar radiation, and other important parameters. Work began in the Antarctic coincident with the International Geophysical Year (IGY) and the support of the National Science Foundation. In 1971, Point

Barrow, Alaska, was selected for the site of an observatory. With the assistance of the U.S. Navy's Polar Program Office in the Office of Naval Research and the Naval Arctic Research Laboratory, the construction of the necessary building, road, electrical power, and instrument platform was complete by the end of 1972. A program of CO_2 flask sampling and daily Aitken nuclei counts began in April 1971 with the cooperation of the Earth Sciences Laboratories of NOAA. These measurements have confirmed the use of the site for background measurements. The first staff assignment and the "official" beginning of the program is in January 1973.

At Tutuila Island Samoa, a preliminary survey is underway. The location was chosen, with the assistance of the staff of the National Geographic Society, as the best within the means of the program and is ideally located in the Southern Hemisphere trade wind belt. The assistance of the Government of American Samoa and of the Chiefs and people of Tutuila in locating suitable sites and the interest and help of Governor John M. Haydon and his staff are gratefully acknowledged. A preliminary program conducted with the assistance of the National Weather Service of NOAA has made possible atmospheric turbidity measurements and collection of precipitation for chemical analysis was begun in 1973.

We recognize that our planned measurements do not now encompass the multitude of desirable related research programs in atmospheric physics and chemistry. Our facilities will therefore be available for cooperative programs whenever possible within the limitations of space and staff. The scope of this aspect of the observatories is shown in section 4.5.

We hope to duplicate and profit from the documentation of others who have previously confronted the problems of acquiring scientific data from remote places and harsh environments. An excellent example is that of the first U.S. scientific expedition to Point Barrow, Alaska in 1882-1883. The leader of the expedition, Lt. P. H. Ray, left guidance (Ray, 1885) we can follow regardless of where we work. He said:

> "...for the work of scientific observation in these high latitudes is one of patient endurance on the part of the observer confined as he is, within narrow limits."

2. DESCRIPTION OF BASELINE STATIONS

2.1 Mauna Loa (MLO)

Hawaii (latitude 19.5°N) is the largest and southernmost island of the Hawaiian chain (figs. 1 and 2). Two mountains dominate the island: Mauna Loa on the south and Mauna Kea on the north side. The observatory rests on the north-northeast slope of Mauna Loa at 3400 m (11,150 ft)

above MSL. A good road joins the city of Hilo on the east side of the island with the observatory. The site is about 780 m below the summit.

Though earlier measurements were made on Mauna Loa, the observatory, as we know it, began in 1955. In the last 17 years, many changes have occurred. For a detailed review of the history of MLO see Price

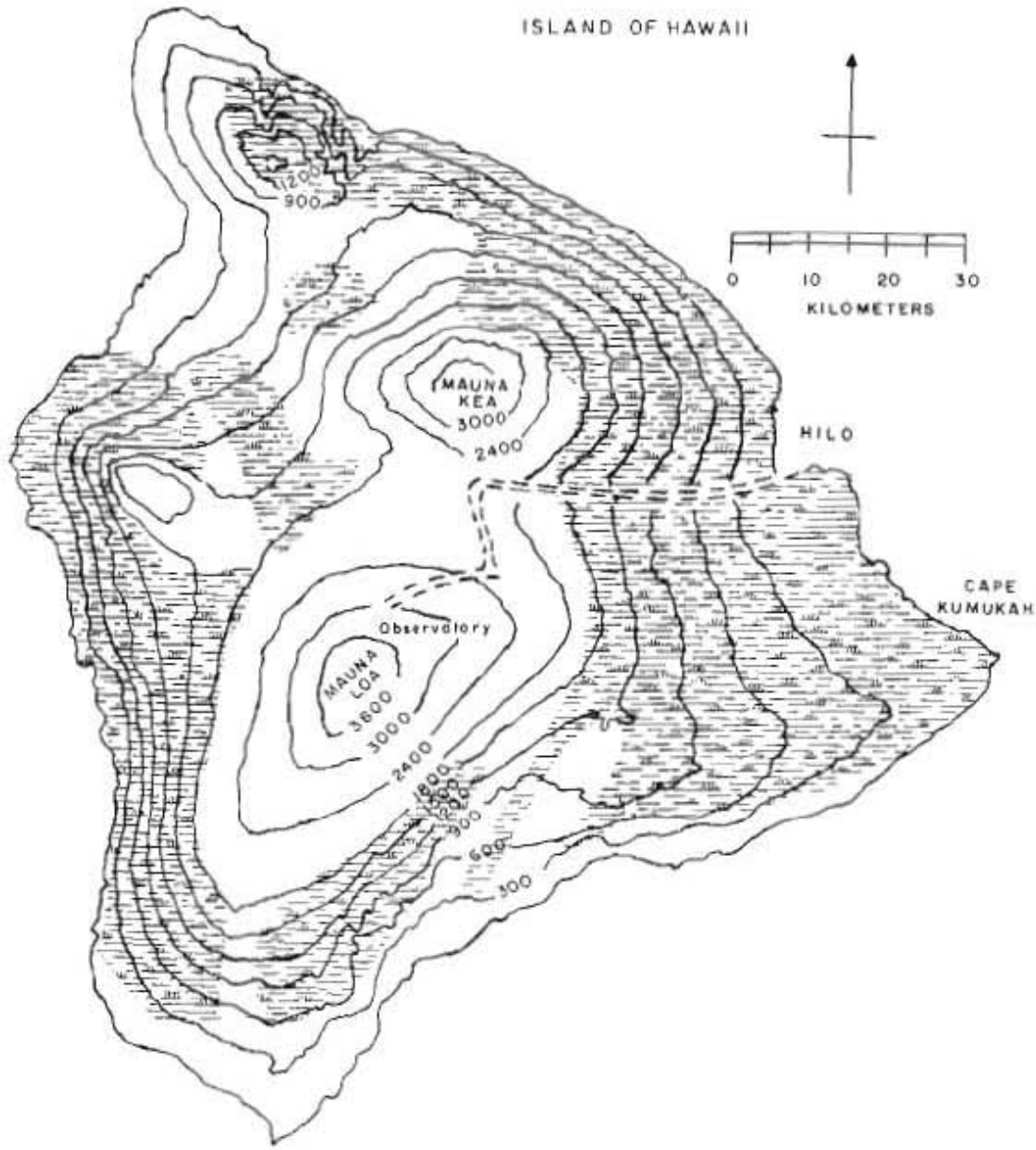


Figure 1. Topographic map of the island of Hawaii (shaded areas indicate vegetation).

and Pales (1963) and Machta (1972). Figure 3 and table 1 are a schematic plan and key to the present site. Panoramic views of the observatory are shown in figures 4 and 5.

Associated with MLO are the staff offices in Hilo. The observatory has a varied schedule that depends on the measurements being made. Besides these two locations, a research site has been established at Cape Kumukahi (sea level) where intermittent measurement programs are accomplished.

Figure 2. ERTS picture of Hawaii.

The persistent tropical trade wind is from the east-northeast, although local drainage and heating affected air flow to a large degree at the observatory site. Evening and large-scale subsidence exposes the site to extremely clean air representative of the middle troposphere. Capping the trade wind is a thermal inversion present about 75 percent of the time at an average altitude of 2000 m, well below the observatory. The trade winds and inversion height mark the top of the mean timberline on the mountain slopes. For a detailed description of the winds see Mendonca (1969). Rainfall below the inversion is heavy; the maximum amount of precipitation is over 7600 mm (300 inches) per year. As a result, the tropical vegetation is luxuriant and beautiful. Above the trade wind inversion, the rainfall is moderate to light; the observatory records about 500 mm (20 inches) per year. There is no vegetation whatsoever within 15 km of the observatory.

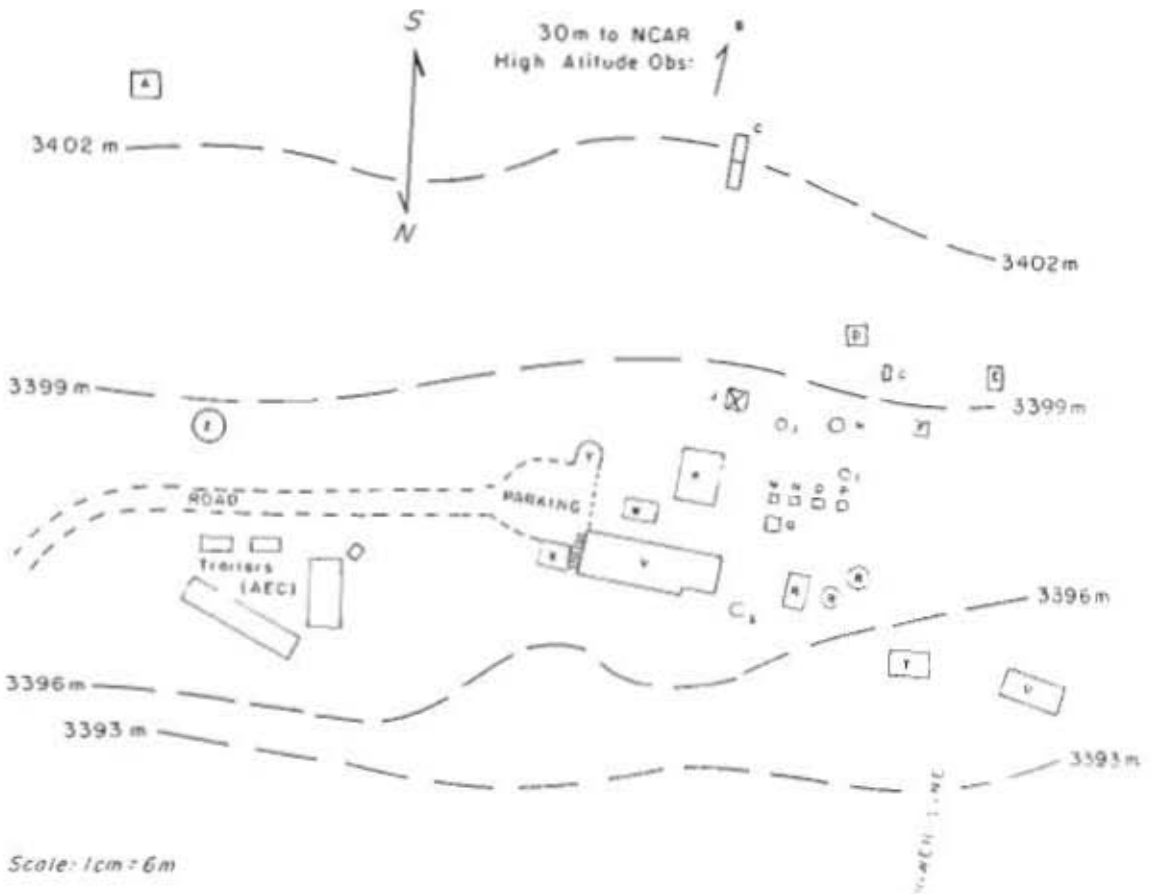


Figure 3. Site sketch of MLO.

Table 1. List of Mauna Loa Observatory Measurements and Location on Figure 1.

	Location Code
Lidar alignment platform and tower.	A
Solor C Study, NCAR High Altitude Observatory.	B
Direct solar irradiance (Eppley Angstrom pyreheliometer).	C
Direct and diffuse solar irradiance (pyranometer).	C
Solar irradiance at 2 IR wavelenghts for atmospheric water vapor.	C
Static collector, spore and bug catcher.*	D
Storage, old darkroom building.	E
Chemical toilet.	F
CO_2 intake tower.*	H
Wind velocity (continuously recorded with cup and aerovane anemometers at 10 and 12 m).	I
Relative humidity (recording hygrothermograph).	J
Surface air temperature (thermometer and thermocouple, continuous).	J,G
Surface dew point (wet-bulb thermometer and thermocouple, continuous).	J,G
Ground temperature (thermocouple, continuous).	K
CO_2 surface concentration.*	V
Data acquisition system.	K
Small particle detector (Gardner counter).	K
Surface SO_2 (bubbler).*	K
Surface NO_2 (bubbler).*	K
Atmospheric pressure (continuous aneroid and Hg barometer for reference).	K,V
Particulate concentration (High volume filter).*	M
Radio nuclides from precipitation*	N
Precipitation chemistry.*	O
Rainfall (tipping bucket and 8 inch standard).	P
Total surface lead and particulates (High volume sampler.)	Q
Fuel storage tanks (unused).	R
Fog concentration.*	S
Line power transformers.	T
Diesel generators (not now in use).	U
Main building: offices, analysis, kitchen, and sleeping quarters.	V
Atmospheric extinction coefficient (sunphotometer).	V
Condensation nuclei concentration.	K
Surface tritium concentration.*	V
Instrumentation building.	K
Elevated sampling and observation platform.	X
Total atmospheric ozone (Dobson spectrophotometer).	Y
Aerosol distribution and concentration (Lidar).	Z
Cloud frequency (extracted from solar radiation data).	B
Cloud type (visual observation).	B
Horizontal visibility (observer estimate).	W
Electronics Shop.	-

*Cooperative program.

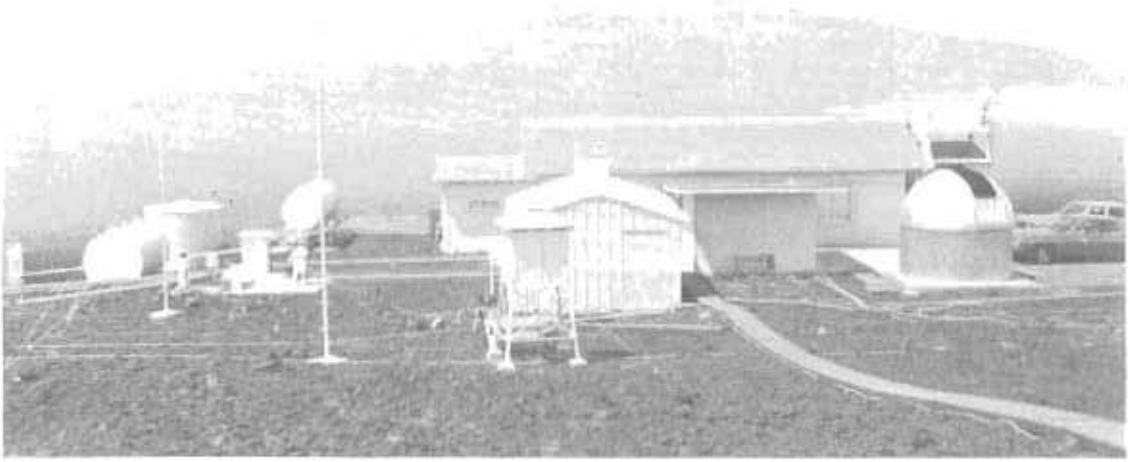


Figure 4. Looking north at MLO with Mauna Kea in the background.

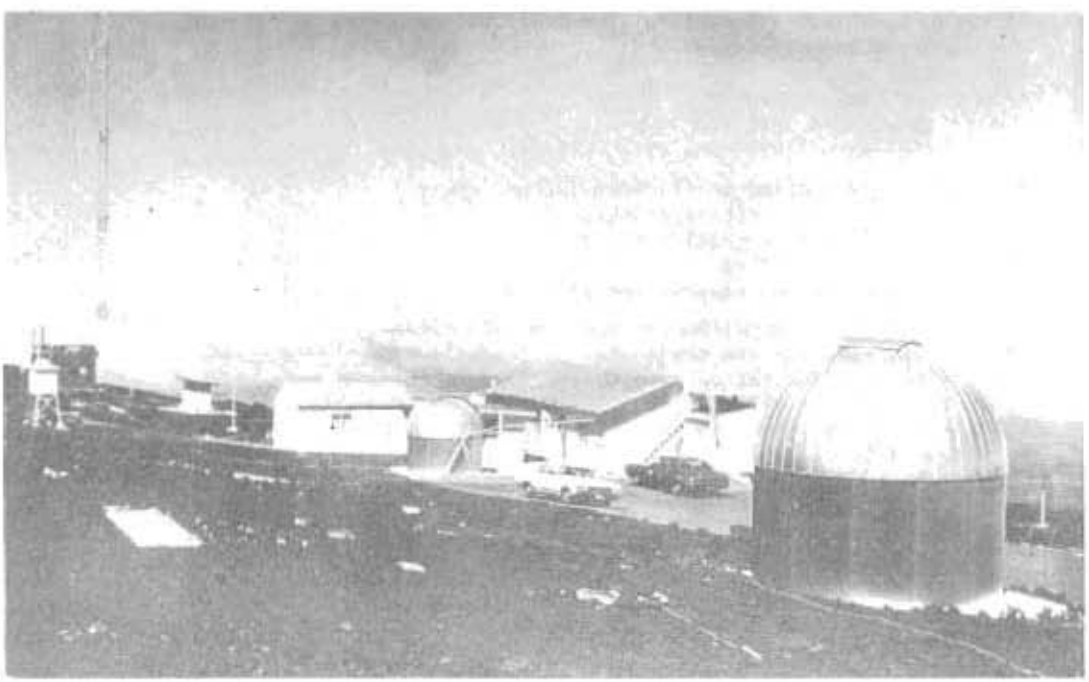


Figure 5. View of MLO (looking northwest) with Lidar Dome in the far right.

2.2 Antarctica (Amundsen-Scott Station - South Pole)

The Antarctic Continent is about 1,425,000,000 km^2. The Antarctic Circle at 66°33'S latitude defines the area that has continuous days of sunlight in summer and continuous days of darkness in winter.

Antarctica is the highest of all continents, averaging over 1900 m elevation, is completely surrounded by oceans, and contains 90 percent of the world's ice. The highest part of the continent is the high polar plateau of East Antarctica where Vostok and Plateau Stations are at an elevation above 3500 m (11,500 ft). The continent has one known active volcano, Mount Erebus (3700 m), located on Ross Island near McMurdo Station. Other prominent mountains include Mt. Kirkpatrick, 4450 m; Mt. Wade, 4570 m; and Mount Markham, 4570 m; all are in the Transantarctic Range. The Sentinel Mountains in Ellsworth Land have Mt. Vinson that is 3410 m.

The South Pole Station is on the greater polar plateau and located only a few hundred meters from the geographic South Pole. The station is on ice at an elevation of 2800 m above MSL with the land below at 108 m. The nearest exposed surface land is the Queen Maud Mountain Range located 400 km to the south along the 180th meridian.

The original buildings of the station were constructed on top of the snow during 1956-57 and have been occupied continuously since then. Today, these same buildings (see fig. 6 and table 2) are approximately 10 m (30 ft) below the surface and interconnected by passageways. A new station is to be constructed nearby.

The nature of some scientific programs necessitate that a few of the buildings must be continually moved in order for them to remain on the surface. Others, located on pylons, are elevated by jacks to escape the drifting snow.

Antarctic weather is dominated by extreme cold, but there is great variation in the average and extreme temperature in different parts of Antarctica. A temperature of -92C has been recorded by the USSR station at Vostok. Temperatures on the Antarctic Peninsula are warmer than in any other area of the continent, with an average of -8C in winter and an average high of -4C in summer.

The sea ice of Antarctica lies around the continent roughly as a barrier reef surrounds a mid-Pacific island. In winter, the sea ice forms a continuous belt 1500-1600 km wide around the continent. In summer the sea ice recedes from the continent, leaving areas of open sea between ice pack and shore. The Ross Sea is generally open in the summer, especially along the 180th meridian.

Annual snowfall in the Antarctic varies from 150 mm in the interior to about 380 mm along the coast. It rarely rains except in the Antarctic Peninsula area. The annual precipitation is so slight that the Antarctic can be classed as a desert. High winds are generally confined to the coastal areas. The average velocity decreases inland to the high plateau of East Antarctica. Because of the uniformly cold and windy

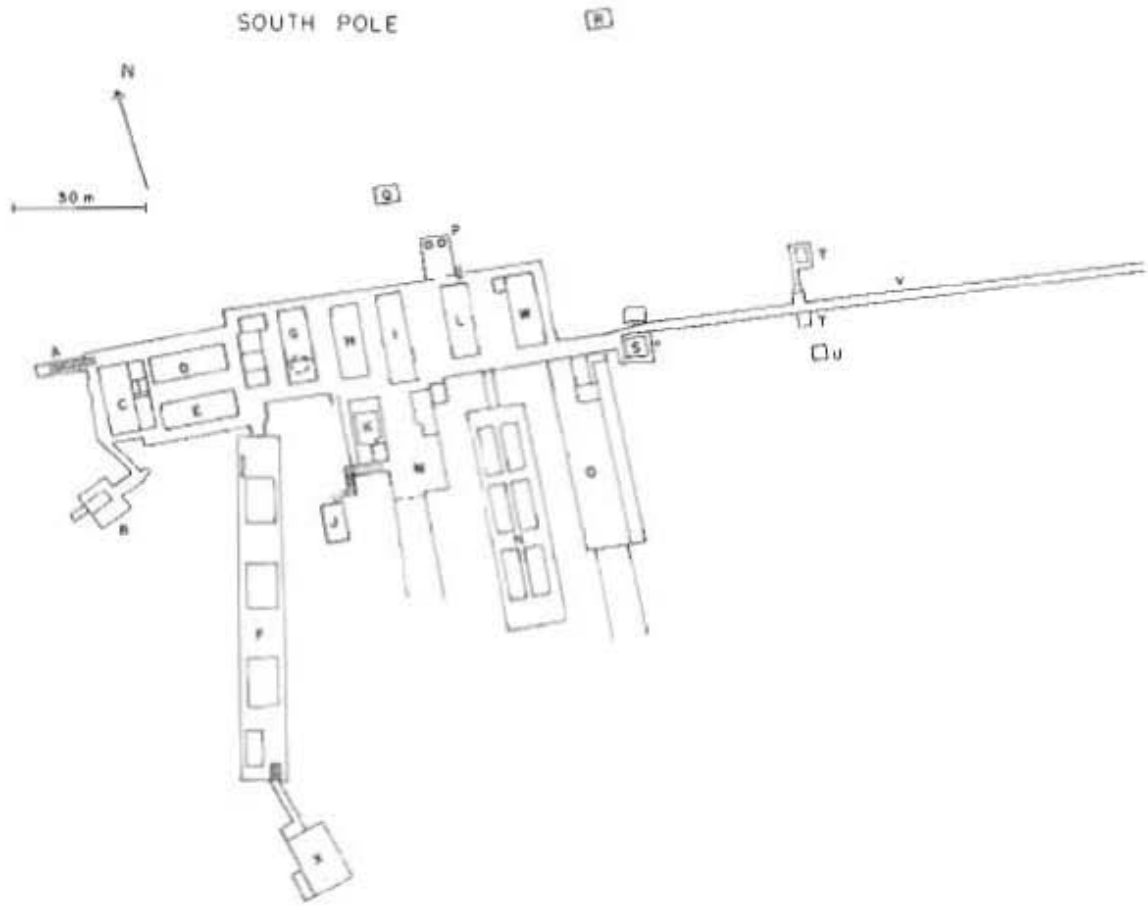


Figure 6. Site sketch of South Pole Station.

weather, especially in coastal areas, Antarctica is known for its lengthy and violent blizzards.

Antarctic climate limits plant life to a few hardy lichens, mosses, and algae in some coastal areas and on scattered mountains exposed above the snow. There are no trees to furnish fuel and shelter.

The mean annual temperature at the South Pole is about -49C. Temperatures range between -21.1C in the summer and -78.9C during the winter. There is only a trace of precipitation and drifting snow blowing across the polar plateau, and this has been the primary factor in the accumulation around the station buildings. The annual average wind speed at the Pole is about 6 m/s.

2.3 Barrow, Alaska (BRW)

Ten years after the United States purchased Alaska from Imperial Russia, Congress sent an expedition to Point Barrow to establish a permanent station (fig. 7). Lt. P. H. Ray, Commander, and his group sailed

Table 2. List of South Pole Locations

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

to Barrow in the summer of 1881. For 3 years, these men gathered information on the meteorology, natural history, magnetism, as well as many other phenomena. The hardships they endured to accumulate the scientific data is a good example to the cold-climate researcher and observer.

The present day Barrow Observatory (71°19'N, 156°36'W; 9 m MSL) is located about 1 km south of Pt. Barrow, North America's northernmost point of land at an elevation of about 9 m. The observatory is on land used for U.S. Navy research and containing the Office of Naval Research's Naval Arctic Research Lab (ONR NARL). The Barrow area is almost in the center of the Arctic coastal plain and on the Arctic Ocean (fig. 8).

The Arctic coastal plain forms a crescent, whose tips touch the Canadian border on the east and Cape Beaufort on the west. Its greatest breadth, about 144 km, is south of Point Barrow. The plain is remarkable for the number of shallow lakes covering its northern portion. During the summer much of the area becomes so swampy that it is impassable. The

Figure 7. Point Barrow station 1882.

plain is so flat that hummocks a few meters high can be seen at great distances. The coastal waters are shallow, with frequent sandbars and islands paralleling the coast. Occasionally the shoreline consists of bluffs, but they seldom exceed 8 m height. Figure 9 shows the observatory in November 1972.[1]

Located on the edge of the Chukchi Sea, Barrow is well within the Arctic Region in climatology. Temperatures remain below freezing through most of the year; daily maxima reach higher than 0C on only 109 days a year. The minimum falls below freezing on 324 days a year. February is generally the coldest month and July is the warmest.

Wind speed varies little with the fall being the windiest. Extreme winds from 15 to 30 m/sec have been recorded for all months. The wind direction is predominantly easterly throughout the year.

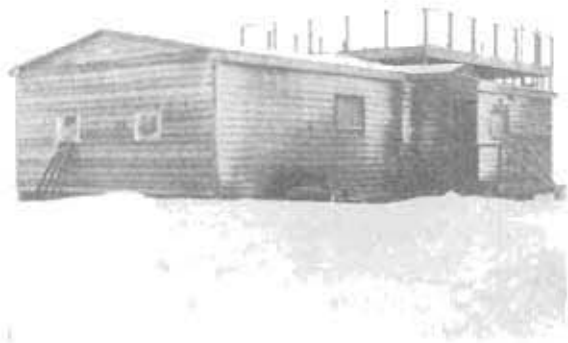
[1]As of this writing, the observatory has been completed. In January 1973, Mr. Dan Williamson, the first GMCC Station Chief, began observations.

Figure 8. Map of Barrow area.

The sky cover is least during February, March, and April. Near overcast skies (low stratus) are very persistent the remainder of the year.

Based on 33 years of record, Barrow can expect 60 clear days a year, 53 partly cloudy days, and 186 cloudy days.

Figure 9. Completed Barrow Observatory, October 1972.



2.4 Samoa (SMO)

The Samoan Islands have an interesting history of meteorological observations. Before the World War I, German scientists maintained a meteorological observatory on the island of Opalu (Angenheister, 1924), which is located about 160 km northwest of American Samoa (Tutuila Island). On Opalu, temperature, pressure, humidity, wind, sunshine, cloudiness, and precipitation were measured on a regular basis from 1890 to 1920. (These data will be useful in comparative studies with the new observatory on American Samoa.)

The island of Tutuila is located in the American Samoa Group (14°15'S, 170°34'W), approximately 3160 km south-southwest of Hawaii, 2560 km north-northeast of New Zealand, and 7200 km southwest of California. Tutuila is a long, narrow island lying southwest-northeast, of 177 km^2, just over 32 km long, and from 0.5 to 3.0 km wide (fig. 10). It is volcanic in origin, extremely mountainous, and nearly surrounded by a coral reef. The principal ridge extends the length of the island, reaching a maximum height of 653 m, at Matafao Peak. Vegetation is moderately dense, with many coconut, banana, and other tropical fruit trees, grass, and low-growing brush.

The location selected for the Geophysical Monitoring Observatory is Cape Matatula (fig. 11). The cape is situated at the extreme northeast end of the island and includes a rocky promontory (with sparse vegetation) suitable for air sampling as it is removed from the lush vegetation prevalent over most of the island (fig. 12). The promontory is 18 to 21 m above the Pacific Ocean. The edges of the cape fall abruptly to the sea which is deep along this portion of the coastline (fig. 13). The village of Tula is 1 km to the south and is located on the extreme northeast end of the island's paved road system. Electrical power in Tula is supplied by the generating plant in Pago Pago.

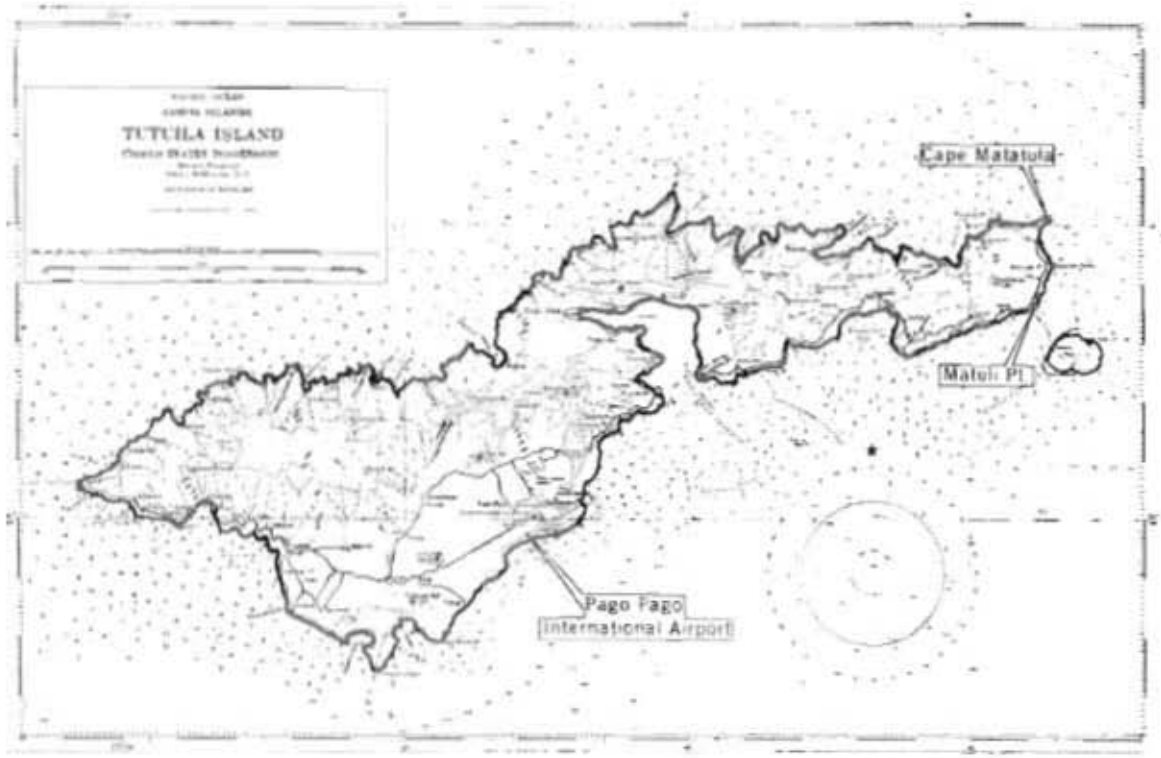


Figure 10. Map of Tutuila Island.

The communal ownership of the cape is an important consideration in the negotiations in locating the observatory. Cheif Tagi Iuli, shown in figure 14, is one of the Samaons who represented the interests of the community in these discussions.[2]

The available climatological data have been acquired from the Tafuna Airport about 16 km to the southwest of Cape Matatula; hence the data can be viewed only as indicative of the conditions to be expected. The prime climatic consideration at the cape is the wind direction. A study of 3 years of data shows the wind averaging 3.7 m/s comes from the east-northeast, east and east-southeast 78 percent of the time. The location of Cape Matatula shows that these wind directions would mean uncontaminated air for sampling.

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[2]As of this writing, the negotiations have been completed. Mr. Vern Rumble, the first Station Chief, is now in Samoa and has begun observations.

Figure 11. Topographical map of Cape Matatula.

The average temperature is about 26C, with an almost constant 80 percent relative humidity. The total range of monthly average temperatures is only 3C, with the coolest monthly average occurring generally in August (25C) while the warmest monthly average is usually recorded during December (28C).

Based on 1968, 1969, and 1971, the cloudiness to be expected is as follows: clear days, 30; partly cloudy, 137; cloudy days, 198 a year.

Figure 12. View of Cape Matatula from the ocean.

Figure 13. View of Cape Matatula from promontory.

Figure 14. Chief Tagi Iuli.

2.5 Planned Stations

In addition to the four stations already mentioned, two others are being planned. One will be on the west coast of the United States. As yet no definite location has been chosen. The second station will be farther east, either on the coast or possibly as far east as Bermuda, which shows good promise both logistically and meteorologically. Professor R. A. Duce of the University of Rhode Island has begun a program of trace sampling measurements which seems to show the suitability of Bermuda for the GMCC program.

When these two observatories are established, the GMCC network of U.S. operated remote observatories will be completed.

3. OBSERVATORY PROGRAMS

3.1 Mauna Loa

In 1971 and 1972 Mauna Loa observatory experienced a period of growth. Dr. Rudolf Pueschel, Director until July 1972, briefly described this growth in his final report. "The MLO budget increased 85 percent; the number of positions increased from four full time and one postdoctoral appointee to seven full time, one part time and two postdoctoral fellows. Floor space in Hilo was more than doubled. The scientific output in the past 2 years is reflected in three publications, three papers in the review process, and three more papers in preparation. Four talks were presented at scientific meetings by members of the staff." Among some of the major projects instituted under Dr. Pueschel's term as director were:

(1) The Lidar was installed in June 1972.
(2) The new 13-channel solar radiation system was installed.
(3) Several major cooperative studies were established.

In July 1972, Dr. Ron Fegley was appointed director. During the first 6 months while continuing the ongoing programs he placed special emphasis on making the Lidar program operational. These programs will be summarized in the following sections. A list of programs at Mauna Loa is in table 3.

3.2 Antarctica

Mr. Vern Rumble was the observer at the South Pole station during 1971-1972. In November 1971, the Dobson ozone spectrophotometer no. 82 became inoperative. This instrument was replaced by no. 80 in 1972. Surface ozone was measured throughout the period.

Table 3. List of Programs at Mauna Loa

Kinds of Observations	Period	Instrument	Responsible Agency
CO_2 concentration	1971-72	Applied Physics Analyzer no. 58.	GMCC/Scripps
Atmospheric pressure	1971-72	Barograph G210 no. 1318.	GMCC
Atmospheric pressure	1971-72	Mercury Barometer no. 723.	GMCC
Amount of precipitation	1971-72	Rain Gauge Standard and recording.	GMCC
Temperature and dew point	1971-72	Two Hygrothermographs (Friez) no. 7178 and no. 7199.	GMCC
Surface ozone	1971-72	Mast Oevelopment Co. Ozonemeter no. 187730.	GMCC
Solar radiation	1971-72	Two pyranometers 10 junction no. 1833 and no. 1825.	GMCC
Solar radiation	1971-72	Two pyrheliometers 50 junction no. 3287 and no. 2119.	GMCC
Total ozone	1971-72	Dobson spectrophotometer no. 63.	GMCC
Radio nuclides in precip.	1971-72	Ion exchance column.	AEC
Total surface particulate matter	1971-72	High volume sampler.	AEC Health & Safety Lab
Total surface particulate matter	1971-72	High volume sampler.	EPA
Surface tritium concentration	1971-72	Molecular sieve.	U of Miami
Aitken nuclei concentration	1971-72	Pollak counter.	State University of N.Y.
Surface SO_2 and NO_2	1971-72	Chemical bubblers.	EPA
Precipitation collector for chemical analysis	1972	Automatic opening rain collector.	GMCC/EPA
Fog concentration	1972	Fog collector.	U. of Hawaii at Hilo
Atmospheric extinction	1971-72	Various filter photometers.	AFCRL
CN/Aitken counter	1972	Gardner counter.	GMCC
Total solar energy	1972	Wig Wag pyranometer.	Hawaiian Sugar Planters Assoc.
Wind	1971-72	Recording anemometers.	GMCC
Atmospheric turbidity	1972	Eppley Model DA Sunphotometer (380 and 500 nm).	GMCC

3.3 Barrow, Alaska

The selection of Barrow, Alaska, as a location for a GMCC Arctic baseline station was based on an evaluation of several Alaskan locations. To meet WMO guidelines for baseline stations, we found that although other Alaskan locations offered longer periods of background air mass conditions, their use as baseline stations was too difficult and too costly. In order to determine that Barrow would have a "baseline" mode for a large part of the time, we measured Aitken condensation nuclei and took CO_2 flask samples for 1½ years. This verified that with wind speeds greater than (3 m/sec) locally uncontaminated air could be measured 60 percent of the time at the selected location. This site is also exposed to on-shore flow off the Beaufort Sea about 40 percent of the time. This flow represents the normal northeast circulation of this Arctic region which, when reaching the Barrow coast, has crossed only over sea and ice.

The first pilings for the laboratory were set in late spring of 1972. Delays were expected because the permafrost permits only seasonal types of construction, and the other scientific programs demand most of the contractor resources during the summer. In early fall 1972, a three-wire pole line and a road bed was completed from the DEW-line site. Except for heaters, electrical wiring, floor, and ceiling tile, the laboratory building was complete by the end of 1972. In addition, pilings for the Dobson and tower platforms had been placed. During this construction, Earth Sciences Laboratories/NOAA continued Aitken nuclei and CO_2 flask samples at the geomagnetism building west of the new laboratory. The first station chief at Barrow was hired on 15 November and after a 6 week training period with the Techniques and Standards group in Boulder, began duty at Barrow January 15, 1973. An agreement for operational support services was made between GMCC and the Office of Naval Research, Arlington, Va. A pick-up truck was procured in October.

3.4 Samoa

Appraisal of several Pacific islands led to the selection of the island of Tutuila of American Samoa as an excellent possibility for a Southern Hemisphere baseline station. Two preliminary expeditions, one in April 1972 and another in September 1972, were made to Samoa to take Aitken measurements and CO_2 flask samples to determine if Cape Matatula, at the northeast end of the island, had clean air and background conditions. Both expeditions indicated this to be true, and land access negotiations began with the local owners. At the other end of the island, at Tafuna airport, the National Weather Service (NWS) operates a weather station which includes radiosondes twice daily. With their cooperation, housing and office space was obtained from NWS, and they agreed to install a precipitation chemistry collector alongside their rain gages. NWS also measured turbidity for the Environmental Protection Agency (EPA) at Tafuna.

The second expedition to Samoa included National Center for Atmospheric Research (NCAR) personnel; they found that the Cape Matatula site would be excellent for their multi-gas measurement apparatus used to determine background trends of trace gases. 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 program, a decision would be made whether to build a permanent observatory that would continue this data and whether to add the other component systems.[3]

4. MEASUREMENT PROGRAMS

4.1 Gases

4.1.1 Carbon Dioxide (CO_2)

Principle of CO_2 measurements. Observations of CO_2 are important for delineating the secular increase in atmospheric CO_2 caused by combustion of fossil fuels, and for determining the partitioning of man-made CO_2 among the major CO_2 sinks, viz., the atmosphere, oceans, and biosphere. Such information can be useful for predicting future CO_2 global pollution levels and, also its possible effects on infrared (IR) radiation absorption.

The most sensitive instruments currently in use for measuring CO_2 are nondispersive type IR CO_2 analyzers. Several different commercial instruments are available; all operate basically on the same principle. As originally described by Smith (1953), the instruments all measure the loss of energy of a beam of IR traversing an air sample containing CO_2.

A particular analyzer used at the GMCC Techniques and Standards Group laboratory in Boulder, Colorado, is manufactured by Mine Safety Appliance Co. of Pittsburgh, Pennsylvania, and operates as follows. Infrared radiation emitted by a glowing nichrome filament is mechanically chopped at 20 Hz and directed through the gas sample cell into a detector cell that is permanently filled with CO_2 diluted with Argon. The radiation absorbed by the CO_2 gas in the detector cell produces a cyclic pulsation in pressure that is transmitted to a tantalum diaphragm of a condenser microphone and converted to an alternating voltage, amplified, and recorded. The CO_2 in the atmospheric gas sample reduces the radiation reaching the detector cell at just those wavelengths at which absorption can be detected. Thus, the voltage developed by the detector varies inversely with the concentration of CO_2 in the sample.

Infrared CO_2 analyzers either can continuously measure atmospheric CO_2, such as those at Mauna Loa, or can analyze CO_2 flask samples. A

[3]The location has been determined to be adequate and construction planning and land-use negotiations are underway.

500-mℓ flask for sampling CO_2 is constructed of Pyrex glass. At each end of the flask an oblique bore glass stopcock is connected to a 14/35 mm male standard taper joint. The stopcocks are lubricated with Apiezon grease. To obtain an air sample for CO_2 analysis, we attach a hand aspirator to the flask by a greased 14/35 mm female standard taper joint. While facing into the wind, the observer holds his breath, takes a few steps forward, and opens up the flask stopcock that is fartherest away. Quickly opening the near stopcock also, the observer rapidly pumps the hand aspirator 40 to 50 times. The sampling is completed by closing the stopcock in reverse order. To increase the reliability of the data, we usually collect flask samples in pairs.

Calibration of the CO_2 analyzer. A CO_2 analyzer is calibrated by passing CO_2-in-N_2 reference gases of known calibrations through the instrument. Although a number of commercial firms can supply reference gases of desirable quality, the gases are calibrated at the Scripps Institute of Oceanography, University of California at San Diego, under the direction of C. D. Keeling. He established a set of primary standard CO_2 reference gases early in the 1960's by using a highly accurate manometric calibration method. All new tanks of CO_2 reference gas are calibrated relative to Keeling's primary standards.

A new "gas synthesis" method of absolute calibration of CO_2 reference gases was recently devised by W. D. Komhyr (1972) of the GMCC Techniques and Standards Group in Boulder, Colorado. His method combines accurately known volumes of pure CO_2 and N_2 under identical conditions of temperature and pressure. A prototype apparatus has been successfully tested, and work is underway in fabricating an apparatus to be used for routine calibrations.

Data summary. The Mauna Loa index values of continuous CO_2 measurement are shown in table 4. These values will be adjusted when final

Table 4. CO_2 Index Values - A Monthly Average for the Period, January 1971 - July 1972

1971	Index (ppm)	1972	Index (ppm)
Jan.	320.75	Jan.	321.42
Feb.	321.16	Feb.	322.17
Mar.	321.59	Mar.	322.60
Apr.	322.17	Apr.	323.35
May	323.17	May	323.77
Jun.	322.92	Jun.	323.00
Jul.	321.84	Jul.	322.44
Aug.	320.34	Aug.	320.78
Sep.	318.75	Sep.	319.54
Oct.	318.92	Oct.	319.70
Nov.	319.92	Nov.	320.82
Dec.	320.84	Dec.	321.91

calibration is completed by Prof. C. D. Keeling of the Scripps Institution of Oceanography, La Jolla, California. Figure 15 shows the equipment at Mauna Loa.

The monitoring of atmospheric CO_2 by the glass flask method was commenced in 1967 by the NOAA Environmental Research Laboratories in Boulder, Colorado. Numerous short-term sampling programs have been conducted. Those having records long enough to render the data especially meaningful are listed in table 5. Tables 6 and 7 give CO_2 data obtained at two of our sampling sites: Barrow, Alaska, and Ocean Station Charlie (52°45'N, 35°30'W). The CO_2 concentrations shown in the tables are index values that are sugject to a small manometric correction.

In 1972, two UNOR infrared CO_2 analyzers (manufactured by H. Marhaki Ag, Hamburg, Germany) were procured for the continuous CO_2 monitoring programs. One will be sent to Barrow, Alaska, during the summer of 1973, and the second for the South Pole Station, Antarctica, will begin operating early in 1974.

4.1.2 Total Ozone (O_3)

Total O_3 observations by the Dobson ozone spectrophotometer were first made in the early 1950's by the U.S. Weather Bureau. The program gained impetus during the International Geophysical Years (1957-1959). During the early 1960's the observation program was revamped, since that time a nearly continuous record of observations has been available. A brief history of the U.S. total ozone observations program, since 1961, has recently been recorded by Komhyr et al. (1972).

Principle of ozone measurements. The Dobson ozone spectrophotometer (fig. 16) measures O_3 by comparing the relative intensities of selected pairs of wavelengths in the Huggins O_3 absorption band (3000-3250A). A rotating sector wheel within the instrument allows each wavelength to pass alternately to the cathode of the photomultiplier tube, which produces a variable output that is amplified by an a-c amplifier, rectified

Figure 15. CO_2 measuring equipment at MLO.

Table 5. CO_2 Flask Sampling History

Location	Elevation in m	Date Start	Date End	Remarks
Niwot Ridge	3750	Feb 68	---	
Flagstaff Mtn. (Boulder Mtn Park)	2130	Feb 68	Feb 71	Measure vertical concentration differences.
Barrell Mill	1650	Dec 68	Oct 70	
Ocean Weather Sta. "Charlie"	Sea Level	Nov 68	May 73	
Niwot Ridge Diurnal Study	3050	16 Jan 68	17 Jan 68	Exposed over 80 flasks during 24 24 hrs. Also measured Aitken Nuclei and windspeed and direction.
Arctic Cruise	Sea Level	Apr 67	Nov 67	Flask samples taken at 80 locations around the world.
Mauna Loa – Above and Below Temp. Inversion	2100-2400 3410	Aug 69	Sept 70	
Mauna Loa – Aircraft Samples Around the Island of Hawaii	variable up to 3410	24 Nov 70 3 Dec 70	same day	The object was to sample air above the "typical marine layer" at the observatory elevation, 2 days.
Ice Island T-3 (1)	Sea Level	19 Dec 68	same day	
(2)	Sea Level	21,24,628 Mar 69	same day	Located near 130°W, 85°N.
(3)	Sea Level	Jan 71	Apr 71	Located near 30°W, 85°N. This set taken during a series of balloon ascents to study the vertical structure of O_3 and the spring "burst".
German Vessel "Meteor" 10°S to 60°N – Central Atlantic	Sea Level	Apr 69	May 69	17 separate sampling locations.
Pt. Barrow, Alaska 71°N, 157°W	9	Apr 71	---	Sampling started to check selected observatory location for cleanliness. Program continues.
USCG "Staten Island" around Antarctic	Sea Level	Feb 71	Mar 71	
American Samoa Cape Matatula	21	Jan 72	---	Samples taken during visits - weekly samples started in June 1973.
Plattsburgh, N.Y.	Surface to 2400	25 Nov 68	same day	Taken on AFF DC-6 on a Weather Mod. flight.
Buffalo, N.Y.	Surface to 3050	22 Nov 69	same day	This was an "Air Pollution Flight"
Barbados Vertical Profile of CO_2	Surface to 3050	9-12 May 69	same day	
Yellowstone Field Research Exper. #1	?	26 Jan 71	3 Feb 71	D.V. Shaffer's group to work near super-cooled water in winter.
Key Biscayne, Fla.	Sea Level	Jul 73	---	Program start in connection with Dr. K. Hansen & the Oceanography group.
High Point Bermuda	Sea Level	Jan 73	---	Site survey - a pair of flasks weekly as at all land locations.

Table 6. CO_2 Index Values for Barrow, Alaska

Date	1st Flask	2nd Flask	Wind Direction	Wind Velocity (mph)
		1971		
25 Apr	330.64	329.94	W	5-6
3 May	326.10	324.62	NNE	12-15
9	325.05	324.86	N	6-8
18	324.96	325.72	S	8-10
24	325.29	325.34	E	15
30	325.68	325.72	SE	2
7 Jun	325.20	325.06	NE	3
15	324.82	324.38	NE	6
22	324.25	322.06	ENE	6-8
6 Jul	321.23	321.23	NE	12-18
13	320.47	318.96	N	5-8
19	315.86	*	E	15-20
27	316.18	315.43	E	8-12
3 Aug	315.73	315.73	W	8-12
10	315.57	315.05	SW	5-8
17	315.72	315.06	SW	5-10
24	314.11	314.44	NE	3-5
31	314.58	314.16	N	5-10
7 Sep	313.73	313.73	NE	10-15
14	318.73	318.30	SSW	8-12
21	319.54	319.58	NNE	3-5
28	316.00	316.56	SW	15-25
11 Oct	317.88	318.16	SSW	2-4
19	319.58	319.72	NE	5-10
26	323.35	323.54	S	1-3
2 Nov	320.29	320.73	NW	8-12
9	320.38	320.38	NNE	20-25
16	325.33	325.77	ENE	12-18
23	323.83	323.69	NW	1-3
30	322.90	322.64	N	1-2
6 Dec	326.89	323.71	----Light & Variable----	
14	330.35	355.20	NW	2-3
21	324.78	324.87	SW	15-20
28	343.81	342.70	NNE	15-20
		1972		
4 Jan	326.23	323.77	N	12-18
11	331.70	327.36	W	15-25
18	327.04	326.80	E	12-18
24	334.94	336.94	ESE	1-2

Table 6. CO_2 Index Values for Barrow, Alaska (con't)

Date	1st Flask	2nd Flask	Wind Direction	Wind Velocity (mph)
		1972		
1 Feb	339.36	333.60	W	2-4
8	329.22	330.74	NE	2-4
15	331.10	328.46	NE	5-8
22	328.24	329.09	SSE	6-10
29	329.87	329.30	NE	6-8
7 Mar	336.36	337.61	S	1-2
14	334.10	330.16	WNW	4-8
22	330.20	329.96	NW	3-5
28	326.46	327.56	SW	6-8
4 Apr	328.44	329.65	W	8-12
18	328.59	329.00	N	20-25
26	326.08	*	ENE	20-30
2 May	330.86	329.05	NNE	2-4
9	327.08	327.08	NE	1-3
15	327.04	326.98	SE	5-10
24	330.40	328.90	ENE	20-25
30	326.22	326.44	NE	8-10

*Broken Flask.

by a commutator, and deflects a needle on an output microammeter. By positioning a calibrated optical wedge in the path of the longer (more intense) wavelength beam, we can reduce the intensity of this beam at the photomultiplier cathode to the same intensity as that of the shorter (weaker) wavelength beam. The photomultiplier tube output then becomes constant and no signal appears in the output of the a-c amplifier. The position of the optical wedge at null point is a measure of the relative intensities of the two wavelengths being measured.

The theoretical basis for total ozone measurements with a ground-based spectrophotometer has been adequately described by Dobson (1957), who also included observational methods and calibration test procedures.

Calibration and quality control. Dobson ozone spectrophotometers are calibrated on an absolute scale by observing direct sunlight on very clear 1/2-days when the total ozone amount is believed to remain essentially constant. The technique enables the "extra-terrestrial constants" to be determined for the instrument at several wavelengths. This method was employed in calibrating our standard Dobson spectrophotometer, instrument no. 83. All other spectrophotometers in our station network have been calibrated by comparing them directly with the standard instrument. This procedure entails simultaneously observing the direct sun at several wavelengths with the calibrated and uncalibrated instruments when the air mass varies between 1.0 and 3.5, and then comparing the results.

Table 7. CO_2 Index Values for Ocean Weather Station "Charlie" (52°45'N, 35°30'W)

Date	1st Flask	2nd Flask	Wind Direction (°)	Wind Velocity (knots)
		1968		
21 Nov*	322.84	322.76	220	25
29	319.38	319.56	250	11
6 Dec	322.49	322.14	220	16
13	321.70	321.14	265	31
21	319.82	320.00	240	20
29	(326.14)**	322.14	155	12
		1969		
5 Jan	320.24	(322.41)	100	22
13	320.97	(322.57)	060	20
20	(321.65)	320.38	350	5
27	(329.13)	324.42	330	18
3 Feb	320.74	(322.34)	170	6
10	(329.60)	320.40	170	18
27	321.54	321.40	290	25
8 Mar	321.87	321.92	360	12
13	322.44	322.48	085	7
15	321.26	321.14	330	25
22	321.64	321.26	015	20
29	(325.08)	(325.65)	210	8
7 Apr	321.68	321.98	250	33
15	322.08	321.90	090	25
21	322.20	322.12	280	15
3 May	(342.02)	(325.78)	110	20
10	322.62	322.68	340	23
18	322.41	(328.22)	250	16
24	322.62	323.12	310	20
31	323.21	323.12	120	26
8 Jun	320.25	320.39	180	15
15	(321.96)	320.66	200	7
23	318.21	318.40	270	12
9 Jul	318.03	(319.31)	220	12
16	317.13	317.03	120	20
23	315.05	314.96	270	5
31	315.60	315.40	290	16
10 Aug	314.88	315.17	240	9
17	314.41	314.71	M	M
23	313.87	314.41	270	12
30	313.57	312.78	210	14

*Responsible Agency 1968-1971 - NOAA-ERL Atmospheric Physics and Chemistry Laboratory.

Table 7. CO_2 Index Values for Ocean Weather Station "Charlie" (52°45'N, 35°30'W)

Date	1st Flask	2nd Flask	Wind Direction (°)	Wind Velocity (knots)
		1969		
6 Sep	(314.76)	312.58	260	15
17	(342.20)	316.40	230	18
23	316.06	(322.62)	295	22
30	330.58	broken	150	15
8 Oct	316.41	316.75	310	25
15	317.14	317.10	210	18
24	317.00	317.06	230	9
2 Nov	317.72	317.76	300	21
10	310.17	320.26	310	41
17	(319.60)	318.64	210	15
24	320.30	320.33	148	3
2 Dec	319.18	319.51	195	23
8	318.84	319.36	180	23
19	(327.06)	320.93	260	20
26	(322.67)	321.21	180	20
		1970		
5 Jan	321.54	321.20	100	25
11	323.08	322.37	090	22
18	323.18	322.94	230	14
26	322.51	broken	200	25
2 Feb	321.98	322.18	270	30
10	>scale	(317.80)	010	13
16	(364.94)	>scale	280	28
18 Mar	324.84	324.22	230	15
26	(339.53)	broken	140	18
5 Apr	(326.74)	324.57	120	35
11	325.14	325.87	115	10
18	323.47	(325.38)	270	30
25	(328.07)	(333.11)	290	4
5 May	323.80	(326.00)	290	40
13	323.80	323.74	080	12
20	322.28	322.47	235	6
30	(326.44)	(327.82)	360	10
5 Jun	(327.95)	(335.38)	260	34
12	320.47	320.34	160	15
2 Jul	319.53	319.36	310	10
9	319.16	318.87	220	21
25	319.90	320.11	310	15

Table 7. CO_2 Index Values for Ocean Weather Station "Charlie" (52°45'N, 35°30'W)

Date	1st Flask	2nd Flask	Wind Direction (°)	Wind Velocity (knots)
		1970		
4 Aug	(326.74)	319.48	210	5
11	(327.85)	317.56	330	28
18	315.78	315.59	200	18
27	(317.12)	314.81	240	17
4 Sep	(341.26)	>scale	310	10
12	317.36	317.50	250	15
19 Oct	322.08	321.90	190	8
25	320.48	320.30	310	14
31	(321.47)	320.60	250	10
2 Nov	320.48	(322.03)	280	18
10	320.44	321.04	290	30
21	(323.44)	321.94	300	20
25	323.22	322.78	020	21
4 Dec	321.57	321.52	190	37
11	322.10	322.49	315	20
24	322.44	322.64	150	8
31	321.47	(326.13)	115	24
		1971		
7 Jan*	325.89	326.13	220	30
11	322.39	322.29	M	M
18	323.72	323.00	M	M
25	323.77	323.44	M	M
6 Feb	324.86	324.29	070	16
15	324.10	324.10	300	13
20	325.24	325.15	210	6
4 Mar	326.76	326.92	120	25
11	327.72	327.29	265	20
18	325.26	324.74	100	8
16 Apr	325.05	324.67	020	8
24	324.34	324.34	220	4
30	324.53	324.10	210	28
15 May	324.06	323.58	210	25
22	323.48	323.44	260	25
27	322.40	322.36	200	17
3 Jun	324.25	323.50	330	30
10	322.36	322.36	100	15
23	320.10	320.00	275	30
30	318.40	318.35	260	20

*Since Jan. 1971 responsible agency is Geophysical Monitoring for Climatic Change - ARL/NOAA.

Table 7. CO_2 Index Values for Ocean Weather Station "Charlie" (52°45'N, 35°30'W)

Date	1st Flask	2nd Flask	Wind Direction (°)	Wind Velocity (knots)
		1971		
7 Jul	319.53	319.53	240	10
14	317.65	317.75	130	13
23	318.83	318.60	040	24
30	316.96	317.06	310	30
7 Aug	317.38	317.24	240	14
14	315.72	315.03	160	10
21	314.63	314.23	300	22
1 Sep	(316.12)	314.96	245	40
10	315.73	(319.63)	330	38
18	317.61	316.94	220	17
24	317.43	317.38	300	26
1 Oct	315.87	316.17	125	22
8	319.63	319.48	110	5
23	318.93	319.48	280	12
31	321.66	321.91	240	38
12 Nov	321.98	321.80	180	8
19	321.12	320.78	190	16
27	322.22	321.65	285	29
		1972		
1 Jan	325.03	324.76	090	12
8	325.74	325.60	300	50
14	326.72	326.24	320	50
27	324.76	324.67	220	32
3 Feb	(328.64)	326.58	200	10
11	324.76	324.76	340	16
12	324.69	324.64	270	16
7 Mar	(330.76)	broken	270	15
27	(327.03)	325.54	100	10
31	325.81	326.13	330	19
7 Apr	325.97	325.86	265	21
24	325.97	325.97	230	10
25	326.40	326.60	340	18
2 May	326.50	326.60	190	12
9	(328.63)	326.14	130	16
10 Jun	322.02	321.82	100	13
17	323.50	323.65	290	15
24	323.85	323.95	270	24
30	322.70	322.49	240	14

Table 7. CO_2 Index Values for Ocean Weather Station "Charlie" (52°45'N, 35°30'W)

Date	1st Flask	2nd Flask	Wind Direction (°)	Wind Velocity (knots)
		1972		
7 Jul	319.94	320.26	270	20
14	318.18	318.18	210	18
19	318.77	318.87	165	12
26	318.00	317.95	220	26
2 Aug	316.58	316.73	170	12
11	315.98	316.07	290	22
18	315.10	314.98	220	28
25	315.81	315.86	220	17
12 Sep	316.73	316.60	160	24
20	315.46	315.46	280	25
26	316.25	316.33	250	22
1 Oct	318.53	318.44	220	18
8	319.18	319.28	310	22
22	(329.10)	321.07	340	17

**Parenthesis indicate questionable data (e.g., samples did not match).

Detailed information outlining observational as well as instrument test procedures, of our total ozone program are adequately described in Komhyr (1962 and 1963). The total ozone data are processed by computer. A FORTRAN program, which incorporates the results from least-squares fitting procedures, accepts as input punched cards and two magnetic tapes. The cards are produced from the sheets containing the lamp test data and those containing the observation data. One magnetic tape contains solar ephemeris data, which are needed for computing the sun's zenith angle. The other tape contains data pertinent to the individual Dobson instruments and where they are located. The printed output of this program includes, amongh other things, a tabular listing of the results for a given station for a given month with up to six observations per day. Each entry in this table contains numerals that indicate the day, nearest GMT hour, value, wavelengths, type of observation, and total amount of O_3 in milli-atmo-cms.

Data summary. A list of stations where we have observed total ozone in the past, or where we are still doing such measurements, is in table 8. Processed data from our station network are routinely sent to Canada for publication in behalf of the World Meteorological Organization (WMO). Copies of the publications, "Ozone Data for the World," may be obtained from Director, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, Canada.

Two recent analyses of total ozone data have yielded the rather surprising result that O_3 may have increased in many parts of the world

Figure 16. Dobson epectrophotometer at MLO.

during the 1960's (Komhyr et al., 1971). The total O_3 increase is particularly well-documented for North America (Komhyr et al., 1972). Figure 17 shows the O_3 trends calculated for the U.S. and the available Canadian stations. The rates of increase (in percent) of O_3 per decade at each station are indicated in figure 18 which also shows mean annual total O_3 isopleths for the period of record (1961-1970). Figures 19 and 20 show the total O_3 measured at the stations listed in table 8.

4.1.3 Surface Ozone

A knowledge of the distribution of O_3 near the surface of the earth can provide useful information for studying transport processes in the atmosphere. Since the source of almost all near surface ozone is the stratospheric O_3 layer, surface ozone is a valuable tool for studying stratospheric-tropospheric exchange processes. An adequate climatology of surface O_3 can shed light on at least three questions: (1) Is there a different process of exchanging O_3 in the Northern and Southern Hemispheres? (2) What is the role of eddy exchange within the tropics and is the eddy exchange coefficient a constant across the equator? (3) How important are the high latitude regions relative to the tropics in the exchange between the stratosphere and troposphere?

Long-term changes in surface O_3 concentrations may reflect changes in the rate of exchange between stratosphere and troposphere; hence they can indicate changes in either the intensity or the location of features of the atmospheric circulation pattern. Such changes, for example, might show up in the latitudinal distribution of surface O_3 or in a phase shift of the annual cycle. At present, the precision of surface O_3 measurements is about ±10 percent; therefore, secular trends must be relatively large to be detected. Changes in the latitudinal distribution or shifts in phase should, however, be considerably easier to detect.

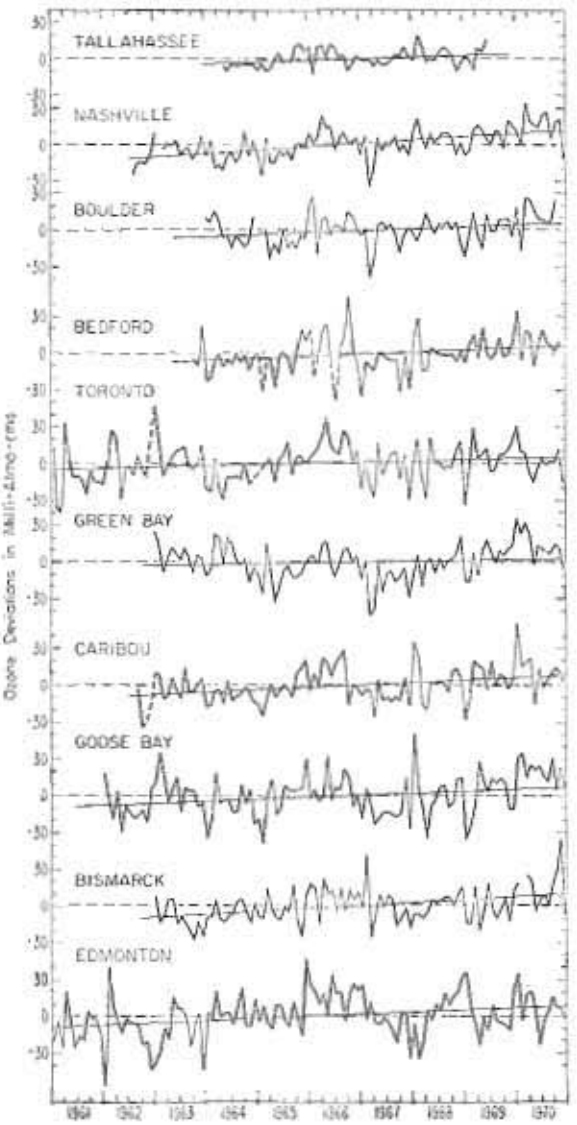

Figure 17. Plots of mean monthly total ozone deviation from monthly normals for North American stations. Linear plots have been fitted to the data.

Operation of ozone meters. Ozone meters currently measuring surface O_3 are the electro-chemical concentration cell (ECC) developed by Komhyr (1969). The meters have an ECC sensor, a gas sampling pump (Komhyr, 1967), a sensing solution flow system, a scrubber for removing interfering sulfur dioxide from the air being sampled, an amplifier, and a recorder. Operation is from 110 V, 60 Hz line power.

The ECC sensor within the meter consists of two bright platinum electrodes; each is immersed in a potassium iodide solution of a different concentration contained in separate cathode and anode chambers. These chambers are linked by an ion bridge of porous Vycor glass; it acts as an ion pathway while preserving the concentrations of the cathode and inode electrolytes. The electrolyte in each chamber also contains potassium bromide and a buffer, but the concentration of these chemicals is identical in each half cell.

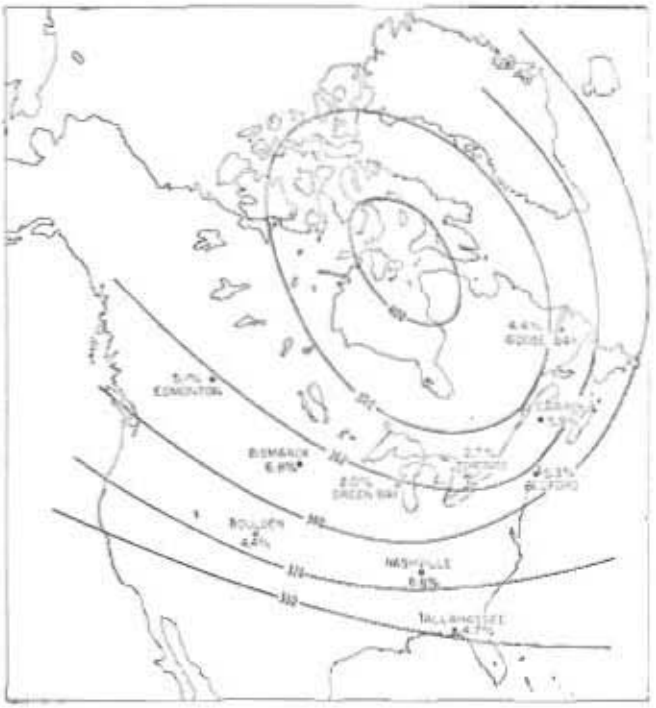

Figure 18. Mean annual total ozone isopleths for the North American continent derived from data obtained during 1961 to 1970.

The driving electromotive force (emf) for the ECC sensor is not applied externally but is derived from the difference of potassium iodide concentrations in the two chambers. For an open-circuited cell first charged with sensing solution, the emf is about 0.13 V. When the cell leads are, however, connected together, this emf forces iodide near the anode to give up electrons to the anode. A sensitive working equilibrium state for the cell is then reached, and the emf drops to nearly zero. If, however, the concentration of iodine (I_2) in the cell cathode chamber is increased by some method, the iodine molecules near the cathode will accept electrons from the cathode and convert them to iodide while iodide near the anode will be forced to give up electrons to the anode and be converted to iodine. The current flowing in the ECC external circuit is thus directly related to the conversion of iodine to iodide or iodide to iodine.

Air containing an oxidant such as O_3, when it is bubbled into the cathode electrolyte, produces iodine according to the relation

$$2KI + O_3 + H_2O \rightarrow 2KOH + I_2 + O_2.$$

The cell then converts iodine to iodide, and the O_3 partial pressure (P_3) in nanobars may be calculated from

$$P_3 = 4.307 \times 10^{-3} \frac{(T)(i)}{F}$$

where i is the ozone current (μA) flowing through the cell and F is the flow rate (mℓ/sec) of the air being sampled at temperature T (°K).

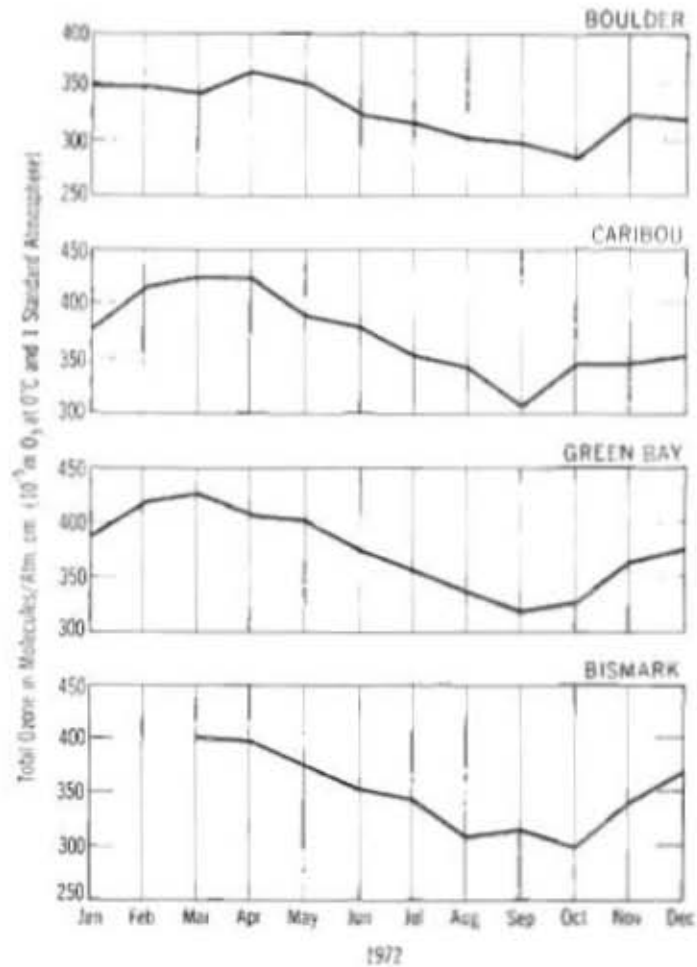

Figure 19. Total ozone for stations, Boulder, Colo.; Caribou, Maine; Green Bay, Wisc.; Bismarck, N.D., and South Pole (1972).

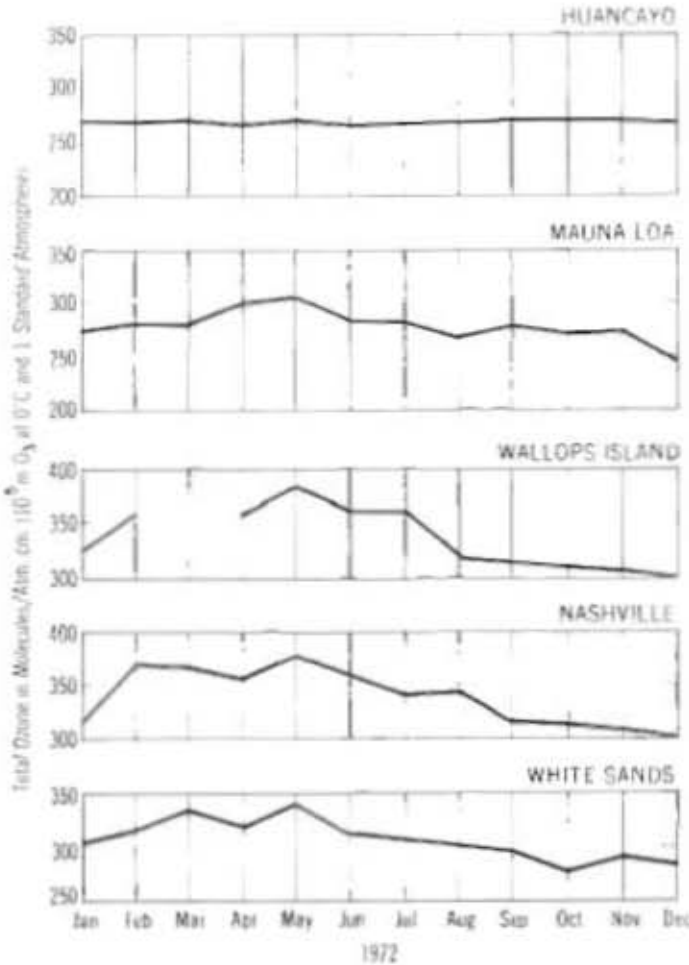

Figure 20. Total ozone for stations, Huancayo, Peru; Mauna Loa, Hawaii; Wallops Is., Va.; Nashville, Tenn., and White Sands, N.M. (1972).

Table 8. List of Stations Which Measure Total Ozone

Station	Spectrophotometer Serial No.	Date	
		Beginning	Ending
Bismarck, N.D.	33	01/01/63	Present
Caribou, Maine	34	01/01/63	Present
Green Bay, Wis.	38	01/02/63	Present
Mauna Loa, Hawaii	63	01/02/64	Present
Wallops Island, Va.☆	72	06/23/67	Present
Nashville, Tenn.	79	01/01/63	Present
Amundsen-Scott, Antarctic	82/80	12/17/61	Present
White Sands, N.M.*	86	01/05/72	Present
Huancayo, Peru☆	87	02/14/64	Present
Boulder, Colo.	91/82 76/80	01/01/66	Present
Tallahassee, Fla.☆	58	05/01/64 06/02/73	03/20/70 Present
Barrow, Alaska	76	08/01/73	Present
Puerto Montt, Chile☆	93	11/18/64	11/30/65
Sterling, Va.	72	01/02/62	06/18/67
Albuquerque, N.M.☆	61	11/11/63	09/19/68
Bedford, Mass.☆	86	10/07/63	01/29/71
Fairbanks, Alaska	76	12/22/64	06/19/72
Canton Island☆	37	02/16/65	04/28/65
Byrd, Antarctic	80	08/09/62	11/30/68
Hallet, Antarctic	37	01/01/61	10/30/63

☆Cooperative Programs.

Calibration and quality control. The recommended technique for calibrating surface O_3 measuring equipment is by comparing with the neutral buffered-potassium iodide method developed by Saltzman (1965). In this method, sampling is conducted in midget impingers containing 1 percent potassium iodide in a neutral (pH 6.8) buffer composed of 0.1 molar disodium hydrogen phosphate and 0.1 molar potassium dihydrogen phosphate. Iodine is liberated in the absorbing reagent by ozone and the absorbance is measured at 352 nm by a spectrophotometer.

We have not yet used the Saltzman calibration method in our work; however, instruments and supplies have been ordered to establish such a primary standard for our surface ozone measurements program. An interim calibration technique is, however, in use and will be compared with the Saltzman calibration method in the future. The current technique consists of

1. providing each observing station with a stable ozone generator that has been calibrated with a reference secondary standard ECC ozone meter (Serial No. 001);
2. checking the performance of the station ECC meter once per month by running it on ozone output by the calibrated generator; and
3. correcting ECC meter surface ozone data, if necessary so as to maintain the calibration level of the standard ECC meter Serial No. 001.

Quality control of the data is further maintained through checks of the computer analyzed results for representativeness and consistency with anticipated results based on theoretical work and previous observations (Junge, 1962; Junge and Czeplak, 1968).

Data summary. During 1972 surface O_3 was observed only at Amundsen-Scott station in Antarctica. The data have been processed and are available from the GMCC Techniques and Standards Group, Boulder, Colorado. Hourly average values, as well as daily means, daily maxima, and monthly mean concentration have been computed for December 1971 to October 1972. The mean monthly values and the average monthly maxima (calculated from daily maxima) are shown in figure 21. Plans call for the publication of such data in *Ozone Data for the World*, published by the Atmospheric Environment Service of Canada in cooperation with the World Meteorological Organization.

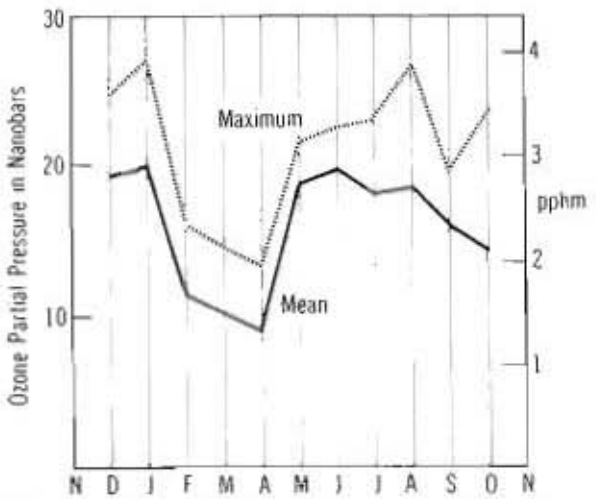

Figure 21. Surface ozone at South Pole measured with an ECC surface ozone meter. The solid curve represents monthly mean surface ozone partial pressures while the dashed curve indicates the average monthly maximum surface ozone partial pressures.

We also have available a considerable amount of surface O_3 data from Antarctica, some obtained as

early as 1961. The data were collected using a variety of instruments. Final processing of the data has begun, and results will soon be available in a NOAA Technical Report.

4.2 Aerosols

4.2.1 MLO Ruby Laser Radar System

Introduction. The primary purpose of the MLO laser radar (lidar) system is to accurately measure the stratospheric scattering properties. Any change over the years in the visible or IR optics of the stratosphere could have a serious impact on the earth's climate. The lidar system was not really operational in 1972. The data presented here are from 1973 and are included in this annual report to illustrate the method. We hope to include more complete data in the next annual report. The Mauna Loa staff is working on techniques to improve the data and a computer system is being installed on-line to fully automate the data analysis.

System description. The lidar system is shown in figure 22. It is at the observatory at 3.4 km MSL. The setting is appropriate because the clear atmosphere reduces degradation of the signal, and the nearness of the stratosphere reduces inverse-square losses. A block diagram of the system appears in figure 23.

Figure 22. Photograph of Lidar system.

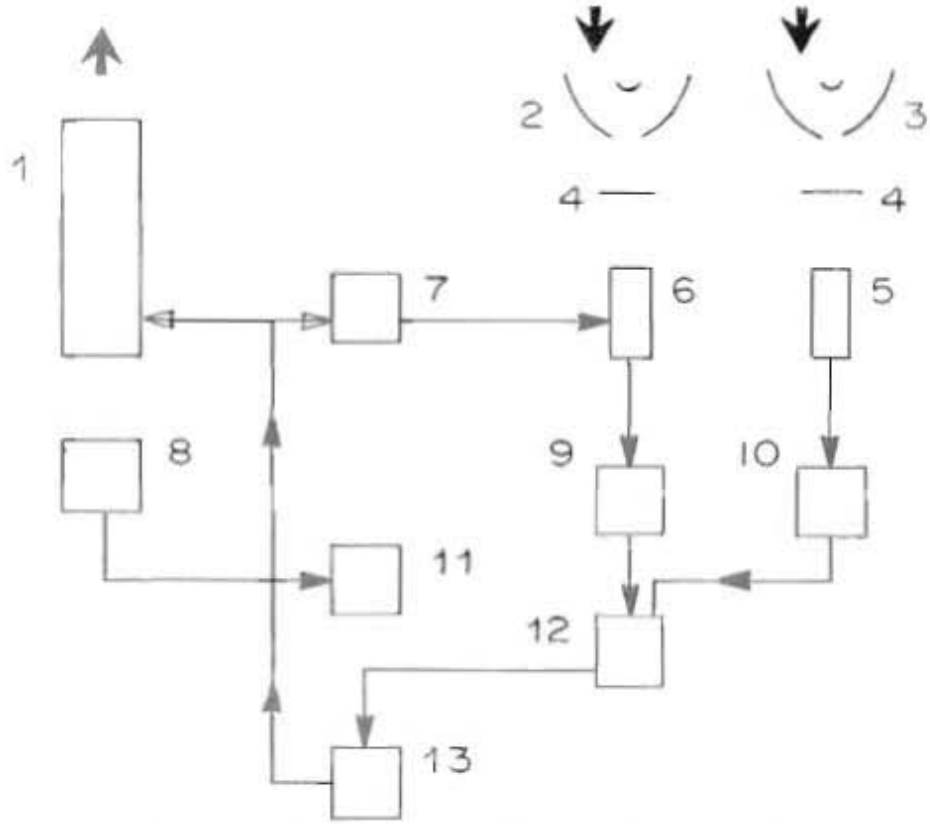

Figure 23. (1) Apollo 3J, 30 ns ruby laser, 2 ppm; (2) 40 cm dia. reflector long range telescope; (3) 8 cm dia. reflector short range telescope; (4) Interference filter, 10A bandpass at 6943A; (5,6) Short and long range photomultiplier tubes, RCA 7265; (7) Long range PMT modulator unit; (8) Photodiode 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.

In the diagram, we see the laser pulses emitted by 1, the Apollo ruby laser. The angular width of the beam is about 10 mrad. The pulse rate is 2 ppm and the pulse duration is 30 nsec, giving a range resolution of 5 m. Pulse energy is about 3J 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 backscattered light from the atmosphere is collected by two telescopes, 2 and 3. The optical axes of the system are aligned using a target about 300 m away. The collected light passes through 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 1 μsec and is then recorded using an oscilloscope-camera combination, 12. A small amount of the laser light is collected and detected at 8. The output is displayed at 11 and is used to normalize the return signals.

Data analysis. The backscattered irradiance at the detector, I(t), is

$$I(t) = kx\ \sigma\ x\ I_0/R^2$$

or:

$$\sigma = I(t)\ x\ R^2/k\ x\ I_0$$

where I(t) is the irradiance as a function of time, k is a system constant, σ is the backscattering cross section (bcs) per unit volume (averaged over the resolution element of the lidar — in this case 5 m), I_0 is the outgoing laser irradiance, R is the range.

Each photograph contains a graph that is proportional to I(t). It usually ranges from 0 to 200 μsec for useful signal return. By averaging several photographs, we get the best I(t), denoted $I(t)_{av}$.

A typical photo output from the system is shown in figure 24. The photos are now being analyzed manually, although this will soon be done by a computer. Each trace is digitized at 4-μsec intervals using a ruler. The upper and lower edges of the trace are read and the result

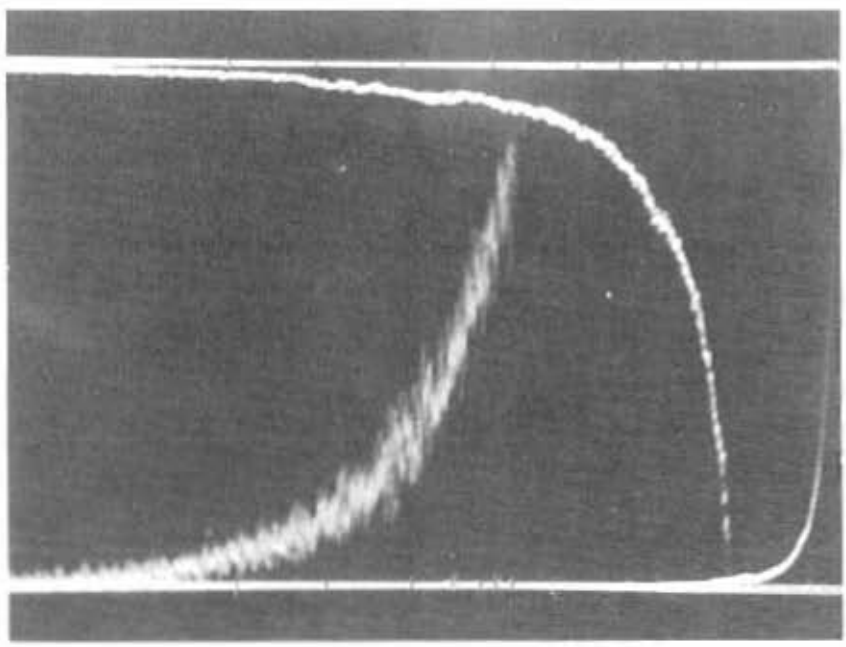

Figure 24. Lidar output signals. Upper trace is long-range telescope output. Sweep rate is 20 μs/cm, which corresponds to a range of 3 km/cm. During first 60 μs, PMT gain is reduced by modular unit. Bright modulator straight line is baseline. Lower trace is short range scope. Sweep rate is 5 μs/cm, or 750 m range per cm. On both traces, time increases to right. On upper trace, positive signal is downward.

averaged. This gives us 30 or 40 values for each trace on each photo, or 60 to 80 values per photo. We usually take 5 shots per evening, giving 5 photos, or 300 to 400 values each evening. The data are then organized and presented by the computer program lidar shown in Appendix A. The output of this program is the relative bcs at each altitude.

Results. The results are shown in figure 25. The Rayleigh scattering is calculated using the NWS rawinsonde data from Hilo. This is plotted at the various altitudes on semi-log paper. The relative bcs calculated from the lidar data are plotted with error bars on a second sheet of graph paper. The graphs are overlaid and matched until the two curves overlap in the 14 km region. The basic assumption in the current analysis is that the scattering from 30 km and some point in the upper region of the troposphere is totally molecular. This assumption probably accounts for the greatest systematic error in the analysis. Finally, a smooth curve is drawn through the relative bcs data. The difference between the two lines at each altitude is then calculated and plotted as the aerosol backscatter.

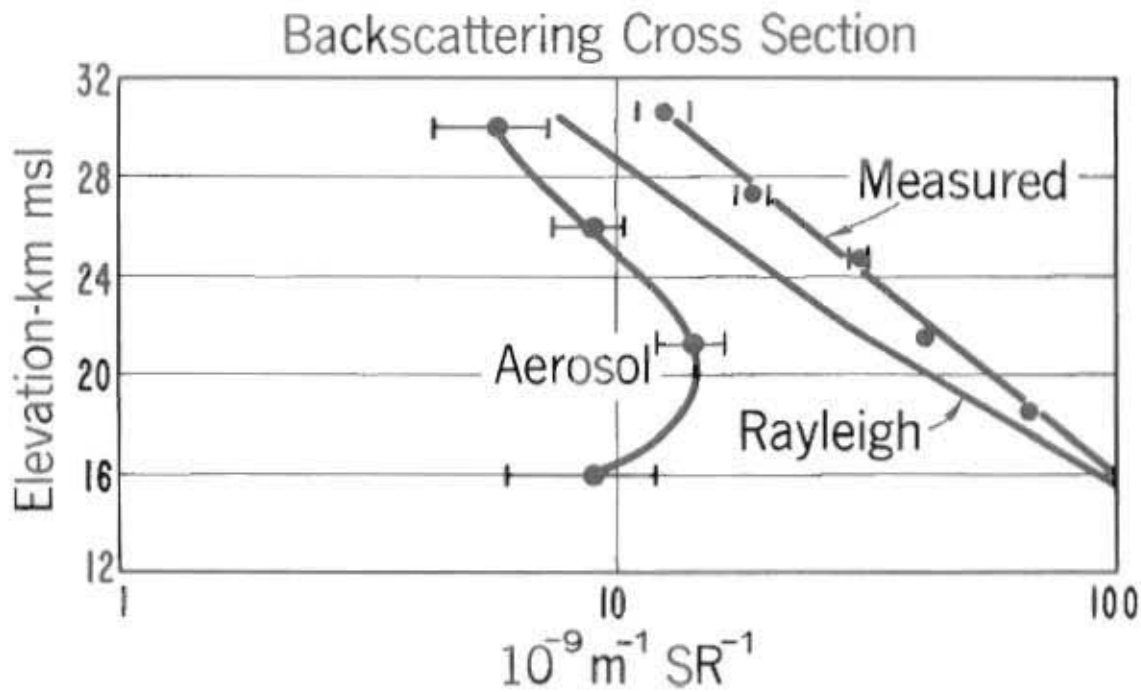

Figure 25. Backscattering cross section. Units are in $10^{-9}m^{-1}sr^{-1}$. Shown are the Rayleigh bcs, the adjusted bcs for the Mauna Loa atmosphere, and the difference between the two attributed to aerosols. The method of adjusting the relative bcs is outlined in the text. The error bars include only statistical error. Systematic errors are unknown at present. Note the relative maximum in aerosol scattering at 20 km.

4.2.2 *Aitken Nuclei Measurements*

Mauna Loa. Aitken nuclei, are airborne particles upon which water may condense under conditions of high supersaturation. These particles are present in one form or another throughout the troposphere and stratosphere, and their diameters range from 0.001 to about 0.1 μ.

It is generally agreed that the troposphere is populated with a background of aged aerosol, primarily of continental origin, at a concentration of the order of 1 to 10 particles/cm^3. At low altitudes over the oceans, the aerosol distribution is dominated by a maritime, or sea-salt, aerosol of about 200 particles/cm^3. At low altitudes over the continents, the aerosol distribution is more complicated, both natural and anthropogenic aerosols occur at approximately 10^4 particles/cm^3. Even higher concentrations occur in urban areas or those of extreme natural pollution (such as volcanos).

An Aitken particle becomes active as a condensation nucleus at supersaturations of about 400 percent, usually produced by a rapid expansion process. All particles larger than 0.001 μ diameter, regardless of chemical composition, will grow rapidly to larger than 5 μ, the particles may easily be detected either optically or photographically.

Aitken nuclei, or condensation nuclei, are not to be confused with cloud condensation nuclei (CCN) or with ice nuclei, two other nuclei measurements often made. CCN are usually measured with a thermal diffusion chamber apparatus at supersaturations of 1 percent or lower. These low supersaturations are used to detect nuclei that may be expected to be aged, hygroscopic, and 0.1 μ or larger in diameter. Ice nuclei are particles that may be expected to be active as sublimation nuclei and are measured through activation in a cold chamber. They are generally non-hygroscopic, such as silver-iodide (AgI), and are needed to initiate the ice phase in cold cloud processes.

Since Aitken nuclei are present in all forms of combustion produces, such as those from automobiles, coal or oil-burning power plants, and other human activities, it is essential to monitor the background tropospheric aerosol concentration in order to assess man's possible impact on his global environment. Aerosols may play an important role in the global radiation balance, because they influence the heat budget and scatter or absorb both incoming solar radiation and outgoing terrestrial radiation.

A widely used instrument for measuring Aitken nuclei is the Gardner Counter. It is a small, portable, hand-operated instrument that gives reliable and reproducible results. It is a light-scattering measurement instrument that uses a humidified chamber, a tube about 30 cm long and 2.5 cm diameter, into which the air sample is drawn. Suddenly the air is expanded and moves into an adjacent evacuated chamber, producing a supersaturation of about 400 percent. Water vapor condenses

upon Aitken nuclei that grow large enough to be detected by a light beam-photocell arrangement. Particle concentration is indicated directly in particles/cm^3.

For many years the Gardner Counter has been used hourly at MLO on each day. See listing of selected data in Appendix B. In general, Aitken nuclei concentrations of about 200 to 300/cm^3 are measured during the morning with values increasing to as high as 2000/cm^3 as the daytime upslope windflow becomes well-established. Nighttime values under well-developed downslope flow are very low, typically less than 150/cm^3. It is not unusual to experience large-scale cyclonic weather systems near the Hawaiian Islands. These can disrupt the trade inversion and the diurnal mountain wind system and produce large-scale mixing between the upper and lower troposphere, which causes Aitken nuclei counts of several hundred/cm^3 for extended times, sometimes up to weeks. Occasionally, volcanic events from nearby Kilauea Volcano can be detected at MLO under favorable wind conditions. No noticeable long-term trends in background Aitken nuclei counts have been observed at MLO; these data provide a good baseline reference for determining future possible global increases.

Future plans for aerosol measurements of Aitken nuclei at MLO include an automated version of the Gardner Counter manufactured by General Electric. This instrument draws a humidified air sample into an expansion chamber, which produces a supersaturation of about 400 percent, and measures light scattering as the Aitken nuclei grow into 5-μ diameter water droplets. This process is repeated continuously at five measurements/sec, as opposed to two measurements/min with the hand-operated Gardner Counter. Thus, round-the-clock Aitken nuclei measurements with good time resolution will be available. This will vastly improve the long-term aerosol particle monitoring capability at Mauna Loa.

Barrow. The Barrow site was chosen with the expectation of occasional interferences from local sources which would necessitate selecting only those samples for analysis when clean air occurs. Daily Aitken nuclei measurements were made with a Gardner small-particle detector from September 1971 through April 1972. Snow covered the ground. These measurements, made in cooperation with the Earth Sciences Laboratory give preliminary information needed to decide which wind directions, particle counts, and other parameters may be collected to decide when clean air is being sampled at the station. Due to the economics of logistical support, no baseline station can be isolated from local pollution sources. The results of these 8 months of Aitken data show that 60 percent of the time the site has a clean air flow.

Four groups of wind directions were picked to represent advection of air from (1) the Arctic Ocean but partly including the Navy runway and fuel storage area, (2) the unobstructed sea to the east, (3) the unobstructed Southeast fetch over the tundra, and (4) the gas wells, the Barrow village, and NARL complex (fig. 26). The three easterly segments will be grouped as representing clean airflow. They account for 60 percent of the winds and have an average particle count of 375 n/cc. This

compares with the 5241 n/cc average for winds from the west. Though great variation occurred in Aitken counts with west winds from 200 to 50,000 n/cc, the three values with easterly segments of flow only varied from 170 to 1200 n/cc. Figure 27 presents these averages schematically, and figure 28 illustrates how well the data conforms to a log normal distribution. Note that over 90 percent of the days fall within Junge's suggested criteria for clean air of 700 n/cc and 50 percent of the days have less than 315 n/cc. In this analysis any wind averaging less than 1.3 m/sec was discarded from the data. The measurement at calm or light winds showed great variability in particle content irrespective of the wind direction, as might be expected.

Figure 29 compares the three clean air wind directions from month to month. Their variability is very similar when we take into account that some of the points represent only two measurements. Outside of the monthly variation, no correlation was obvious between the number of Aitken nuclei and the temperature fluctuation or wind velocity. This preliminary study shows that a majority of the days can be considered valid for sampling.

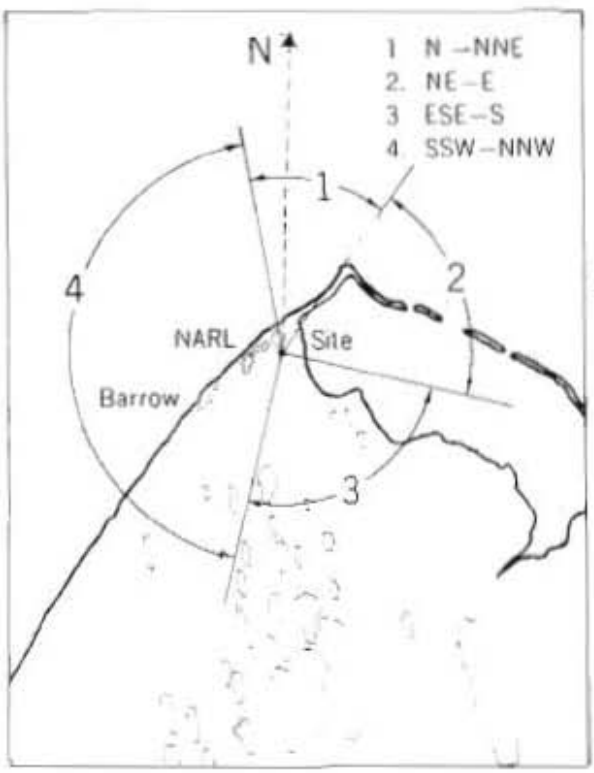

Figure 26. Wind groupings around Barrow Site.

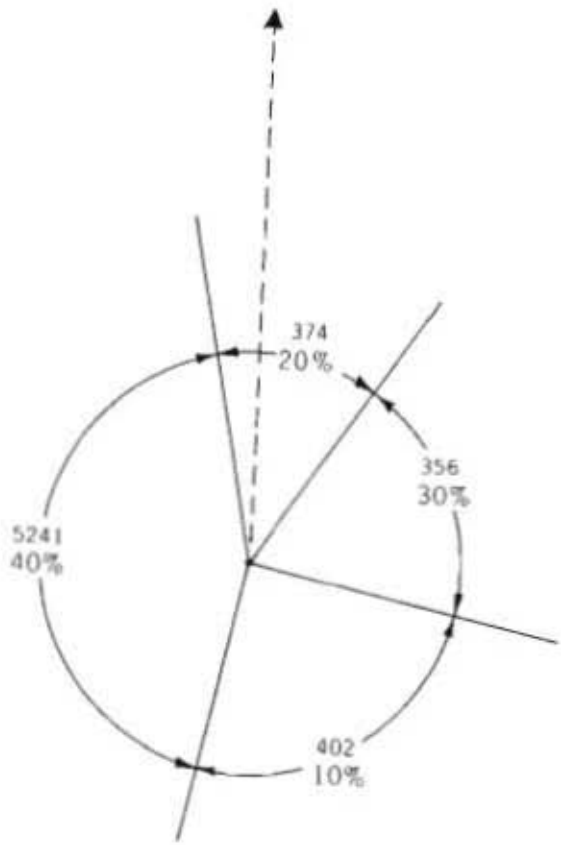

Figure 27. Eight month average Gardner count and wind direction.

4.3 Meteorology

While the specific meteorological instrumentation to be used at each monitoring station will vary according to local conditions, the parameters to be measured will be comparable. In particular, wind and cloud condition data are necessary to establish the validity of specific gas samples and solar radiation observations, and a knowledge of precipitation to interpret aerosol measurements. Furthermore, the performance

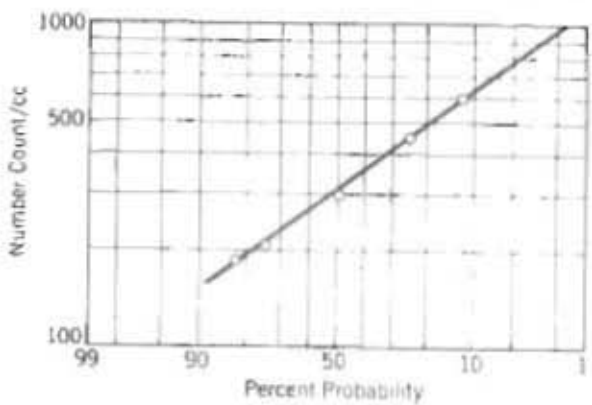

Figure 28. Log normal plot of Gardner count data.

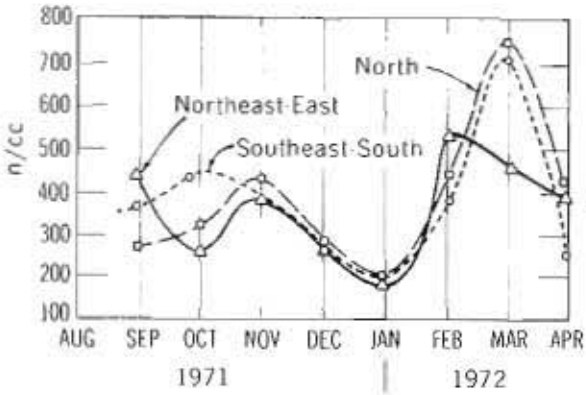

Figure 29. Monthly running mean of Gardner daily count for 3 clean directions.

of all sampling systems depends upon air temperature and dew point temperature. Therefore, instruments will be required to measure five basic meteorological parameters: wind, temperature, dew point temperature, pressure, and precipitation. Cloud cover and visibility can be determined by the observer on duty. In most cases Geophysical Monitoring Observatories are located within a few tens of kilometers of a first-order National Weather Service (NWS) observing station and much guidance and support can be obtained from data collected at such stations although the distance and differences in local terrain preclude the exclusive use of NWS observations. The exception to this situation is at the South Pole Station where monitoring activities will be conducted within a few hundred meters of routine NWS observations.

4.3.1 Wind Measurement

Instrumentation. At both the Mauna Loa and Barrow Observatories an aerovane, consisting of a model 120 wind transmitter and a model 141 wind recorder (Bendix Environmental Science Division, Baltimore, Md.) measures wind speed and direction. During operation, a three- or six-blade propeller of the wind transmitter turns a small d-c generator to produce a voltage that is lineraly proportional to wind speed, from about 1 m/sec to 45 m/sec. Information about the angular position of the vane is sent to the recorder by a syncro-motor system, employing a syncro-transmitter at the sensor and a syncro-receiver at the recorder which operates the recorder pen. The recorder can indicate speed from 1 m/sec, the starting speed of the propeller, to 62 m/sec (120 knots), while wind direction can be recorded over 512°, a procedure that reduces strip-chart "painting" at crossover points. Wind data can be resolved from the strip chart to ±0.5 m/sec and ±2°. Both errors are smaller than those caused by the sensor's nonlinear response to fluctuating winds. Direction accuracy also depends upon the alignment of the sensor. At Mauna Loa, the wind speed is checked against a hand-held anemometer. Furthermore, orientation of the wind vane is checked at least twice annually. A cup-type

anemometer is also operated at MLO; its signal is recorded on a totalizing event recorder (Esterline-Angus) yielding "run of wind" measurements.

Data. Tables 9 through 12 summarize wind observations at MLO for 1971 and 1972.

Table 9. Wind Direction Frequency (%) for 1971

	mps N	NE	E	SE	S	SW	W	NW	Calm
Jan	2.7	1.8	2.2	3.8	10.4	66.4	10.0	2.7	1.0
Feb	5.3	6.6	5.6	38.2	22.9	13.3	2.0	6.2	0.0
Mar	9.6	9.9	6.3	31.0	15.8	13.7	2.6	11.0	1.0
Apr	5.8	7.1	4.7	20.0	18.8	17.1	8.2	18.3	0.5
May	12.2	15.2	7.9	21.1	20.5	9.3	3.5	10.2	0.3
Jun	6.0	16.1	8.2	40.6	15.0	5.4	0.8	8.0	0.6
Jul	8.0	17.7	10.3	35.1	14.0	7.5	1.6	5.7	0.4
Aug	5.7	18.5	8.5	35.3	12.6	8.0	1.5	10.0	0.3
Sep	7.2	22.5	4.3	34.0	15.6	7.3	2.2	6.9	0.7
Oct	8.2	14.9	7.6	38.1	15.7	7.1	1.5	6.9	0.4
Nov	3.8	7.7	8.1	54.5	13.9	5.7	1.0	5.3	0.0
Dec	5.0	5.6	4.2	43.5	17.5	9.2	3.9	9.2	0.0

4.3.2 Temperature and Dew Point Measurement

Instrumentation. A variety of instruments are employed to measure air temperature and dew point temperature, or relative humidity. At MLO, we use standard mercury-in-glass thermometers, a psychrometer, and a hygrothermograph. At Barrow, a dew point hygrometer (Cambridge Systems Model 880, EG&G Environmental Equipment Division) is being used instead of a hygrothermograph. In addition, a multi-point recorder (at MLO) records

Table 10. Wind Speed Frequency (%) for 1971

	mps 0.5-2.5	3-5	5.5-7.5	8-10	10.5-12.5	13-15	>15.5
Jan	17.9	24.0	15.1	10.2	5.9	9.8	17.2
Feb	13.8	34.0	18.5	20.6	10.2	2.5	.5
Mar	19.4	39.8	21.3	13.5	4.2	1.0	.7
Apr	44.2	36.4	11.6	5.1	1.6	.8	.3
May	24.0	47.9	23.3	4.8			
Jun	18.0	33.4	9.8	3.9	1.3		
Jul	25.7	33.5	26.9	13.2	.7		
Aug	25.4	33.8	24.7	12.3	3.2	.5	
Sep	33.3	37.8	20.7	5.3	2.2	.7	
Oct	24.9	41.0	26.8	5.7	1.2	.3	
Nov	12.2	33.3	28.0	18.6	6.1	1.7	
Dec	26.3	29.2	16.8	14.2	10.6	2.1	.8

air temperature and dew point temperature values, respectively, with a thermistor and a lithium chloride dewcell. Soil temperature is also measured. Both air sensors are exposed in an aspirated shield that is designed to limit radiation-induced errors to less than ±0.1°C.

Table 11. Wind Direction Frequency (%) for 1972

	mps N	NE	E	SE	S	SW	W	NW	Calm
Jan	2.8	6.2	3.4	12.5	10.2	39.6	11.5	13.7	0.0
Feb	4.9	6.0	1.8	16.6	18.6	39.6	4.8	7.6	0.0
Mar	3.6	7.7	1.7	10.6	5.2	41.9	16.0	13.2	0.0
Apr	8.2	12.2	4.4	17.7	15.7	14.7	10.0	17.1	0.01
May	8.1	18.9	2.5	18.6	12.4	18.2	4.5	16.9	0.02
Jun	12.5	15.2	4.1	13.2	17.2	21.4	3.9	12.5	0.01
Jul	10.5	14.4	4.1	21.8	20.1	15.0	2.9	11.3	0.0
Aug	12.6	17.3	7.2	17.9	17.3	13.3	5.0	9.5	0.01
Sep	18.7	7.2	6.0	23.3	16.8	14.3	5.6	8.1	0.02
Oct	16.0	7.9	5.0	16.8	19.3	14.7	6.7	13.6	0.0
Nov	5.5	3.0	6.8	47.5	11.5	17.1	6.2	2.4	0.0
Dec	3.5	2.8	2.7	15.3	13.2	51.9	7.8	2.7	0.0

All sensors are, or will be, enclosed in a standard instrument shelter (cotton region type) to minimize the influence of solar radiation. The mercury-in-glass thermometers and the dew point hygrometer temperatures can be resolved to about ±0.2°C, but overall accuracy, when we consider exposure and response, will be about ±0.5°C. The hygrothermograph records air temperatures and relative humidity with a sensitivity and accuracy significantly less than those of the aforementioned units. The thermometers at the Mauna Loa Observatory have been checked

Table 12. Wind Speed Frequency (%) for 1972

	mps 0.5-2.5	3-5	5.5-7.5	8-10	10.5-12.5	13-15	>15.5
Jan	22.5	33.6	18.3	17.4	6.6	1.5	
Feb	14.7	27.4	15.7	21.1	10.9	6.6	3.4
Mar	8.1	26.6	22.6	13.0	17.7	9.3	2.7
Apr	26.0	46.5	19.4	6.1	1.4	0.6	
May	33.1	45.6	19.9	1.4			
Jun	37.1	28.7	10.5	7.6	1.1	1.1	0.7
Jul	35.4	36.3	16.5	8.7	2.6	0.4	
Aug	35.5	42.8	15.4	5.3	1.1		
Sep	36.4	35.2	17.1	10.2	1.2		
Oct	42.3	47.0	10.2	0.4			
Nov	9.2	20.3	30.7	21.3	13.0	5.1	0.4
Dec	6.5	16.9	23.8	20.0	15.0	11.9	5.9

with those at the NWS office at Hilo Airport. The hygrothermograph is checked once a week, or at every chart change.

Data. Figures 30 and 31 show the average maximum and minimum temperatures for 1971 and 1972. Table 13 is a summary of South Pole temperature data.

4.3.3 Pressure

Pressure fluctuations are recorded with a precision microbarograph (built to NWS specification, G210C). This sensitive barometer requires frequent calibration checks, which are performed with a mercurial barometer (built to NWS Specification, G010B). At Mauna Loa Observatory, the mercurial barometer is checked once a year by a standard instrument from the Pacific Regional Office of the NWS. The microbarograph is adjusted to agree with the mercurial barometer twice weekly, or each time the chart is changed.

4.3.4 Precipitation

Both tipping bucket and weighing type rain gages are at the Mauna Loa Observatory. These are standard NWS type D120 and D110 gages. Rain collected is measured with a dipstick after each rainfall. Figure 32 and 33 are graphs of the Mauna Loa precipitation for 1971 and 1972.

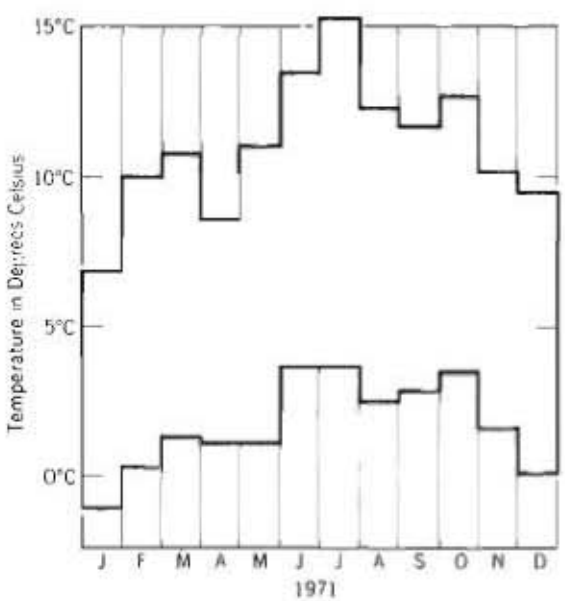

Figure 30. MLO average daily maximum and minimum temperature (1971).

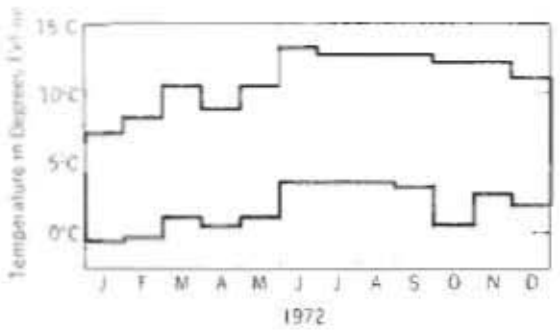

Figure 31. MLO average daily maximum and minimum temperature (1972).

4.4 Solar-Terrestrial Radiation

4.4.1 Aspects of Radiation and History of Observations

Mauna Loa Observatory. As a high altitude observatory in the tropics, the irradiance values are high, approaching 1.70 Langley/min for the direct radiation. The lava that surrounds the observatory for many miles provides a constant albedo that changes only after

Table 13. South Pole Weather Data 1957-1971

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature °C													
Avg. Max.	-27	-38	-51	-54	-54	-54	-57	-56	-55	-46	-37	-27	-47
Avg.	-28	-40	-54	-58	-57	-57	-60	-69	-59	-51	-39	-28	-49
Avg. Min.	-29	-42	-58	-61	-61	-61	-63	-63	-63	-53	-41	-29	-52
Record Max.	-14	-21	-29	-28	-32	-29	-34	-33	-33	-30	-27	-18	-14
Year	1958	1958	1964	1968	1969	1963	1967	1963	1969	1961	1966	1971	1958
Record Min.	-41	-56	-70	-73	-73	-76	-81	-77	-78	-67	-54	-39	-81
Year	1965	1957	1960	1958	1957	1966	1965	1965	1968	1965	1965	1965	1965
Snowfall (After Melting mm)													
Avg. Total	0.05	0.10	T	0.03	T	T	T	T	T	T	T	0.28	1.14
Record Max. Total	0.43	0.69	0.13	0.05	0.05	0.13	T	0.03	0.15	0.10	0.05	0.05	0.25
Year	1958	1972	1963	1971	1971	1963		1963	1971	1958	1971	1971	1958
Surface Wind (mps)													
Prevailing Direction	N	E	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	NNE
Avg. Speed	4	5	6	6	7	7	7	7	6	6	4	4	5
Record Max. 1-min avg.	21	22	16	18	24	19	18	23	23	21	15	13	24
Year	1958	1959	1965	1957	1957	1969	1958	1965	1966	1968	1967	1965	1957

T stands for trace. Record values include 1972 data. Technically, all directions are north from the South Pole. However, for convenience the 0° Meridian is designated as north with all other directions appropriately determined.

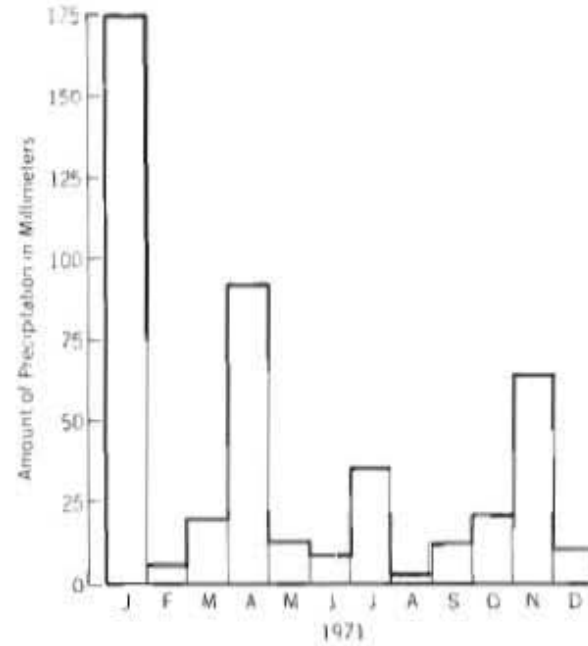

Figure 32. Rainfall at Mauna Loa Observatory for 1971.

an occasional snowfall. This consistancy aids the interpretation of the sky radiation, even though the lava is probably not a Lambert reflector.

Radiation measurements began at MLO in November 1957 as part of the IGY programs. Early instruments included a Beckman and a Whitney net exchange radiometer for terrestrial radiation. Those instruments were

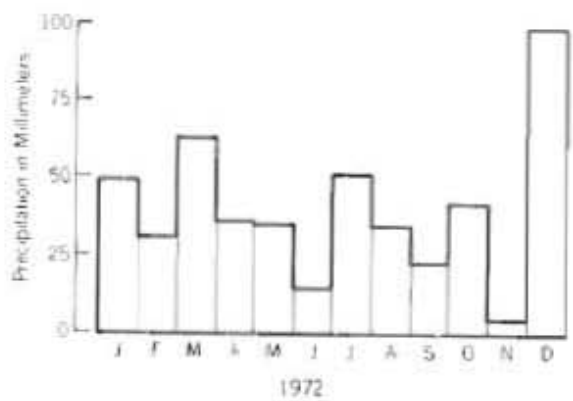

Figure 33. Rainfall at Mauna Loa Observatory for 1972.

used only until 1958 (Price and Pales, 1957; 1963; Fritz and MacDonald, 1962). Then an Eppley normal incidence pyrheliometer (NIP) with manually interchanged Schott filters (types OG1, RG2, and RG8) mounted on an equatorial mount, and a 10-junction model 15 bulb type black and white Eppley pyranometer measured solar radiation. Over the years, as many as eight different NIP's have been used. Pyranometer data were sent to the Data Acquisition Division of the NWS until August 1968, and pyrheliometer data until March 1968. Unfortunately, inadequate quality control and calibration maintenance makes interpretating the results difficult.

Ellis and Pueschel (1971) have analyzed the data in a manner which does not require knowing the calibration constant of the pyrheliometer. Defining the quantity $q = I_n/I_{n-1}$ where I is the direct solar irradiance for the secant zenith angle n corrected for refraction, they obtained an average value for q for each clear day (fig. 34).

Various visitors to MLO have measured solar radiation either for climatological studies or for determining a solar constant. In 1961-62 A. J. Drummond conducted a series of measurements at MLO and Hilo. Drummond and Angstrom (1965, 1966, 1967a and b, 1968) published their results in a series of reports and articles. Stair and Johnson (1958) also made some observations at MLO.

The High Altitude Observatory (HAO) of the National Center for Atmospheric Research (NCAR) now has a spectral hygrometer at MLO to measure total precipitable water (Foster et al., 1964).

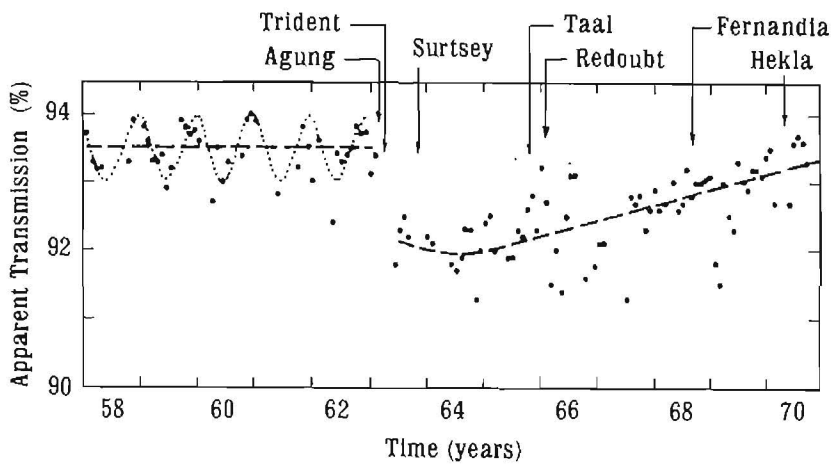

Figure 34. Temporal variations of the monthly means of transmission factors of solar radiation. (From Ellis and Pueschel, 1971).

In 1972, more emphasis was placed on the solar radiation observation program with the acquisition of a new multichannel radiometer, five Eppley Model 2 pyranometers, and two UV radiometers, along with a data acquisition system. These are described in more detail in section 4.4.2.

Barrow, Alaska. Solar radiation at Barrow, Alaska, probably presents a more varied and complex aspect than any other geophysical monitoring station. Lying as it does within the Arctic Circle, this station has considerable periods of twilight, perhaps 40 percent each year. During the day, considerable variations occur in the surface albedo as the snow melts and the local ponds become ice free. Furthermore, the station is near the shores of the Arctic Ocean, and we may expect such phenomenon as "water sky" and the "ice-blink" to occur. A colorful description of this latter phenomenon was given by William Scoresby (1820):

> "On approaching a pack, field, or other compact aggregation of ice, the phenomenon of ice-blink is seen whenever the horizon is tolberably free from clouds, and in some cases even under a thick sky. The ice-blink consists in a stratum of a lucid whiteness, which appears over ice in that part of the atmosphere adjoining the horizon. . .when the ice-blink occurs under the most favorable circumstances, it affords to the eye a beautiful and perfect map of ice, twenty or thirty miles beyond the limit of direct vision, but less distant in proportion as the atmosphere is more dense and obscure. The ice-blink not only shows the figure of the ice, but enables the experienced observer to judge whether the ice thus pictured be field or packed ice. Field-ice affords the most lucid blink, accompanied by a tinge of yellow; that of packs is more purely white; and bay-ice greyish. The land, on account of its snowy covering, likewise occasions a blink, which is more yellow than that produced by the ice of fields."

Ice-blink is an example of one of the multitude of phenomena associated with multiple reflections between ice or snow and clouds. On occasion, the multiple reflections make clouds appear more transparent than they really are. Water sky is the apparent darkening of the sky near the horizon when there is open water in the ice in the distance. The interaction of varying ground surface and varying sky, the presence of the local sea-breeze, and the prolonged twilight at Barrow assure a varied and complex radiation climatology for this station.

The first solar radiation measurements at Barrow occurred in 1882-1883 during the first International Polar Year. Lt. Peter Ray (1885) describes these observations best:

> "Observations on solar radiation were made with a pair of maximum thermometers, one black and one bright bulbed, in vacuo, exposed horizontally on a post 4 feet high on the knoll southwest of the station. They were mounted side by side in a movable frame so they could be brought

into the house in stormy weather. These thermometers were exposed for a short time on November 13 and 14, 1882, just before the departure of the sun, but the latter was too near the horizon to produce any sensible effect. On the return of the sun, January 29, 1883, they were exposed every day not stormy from sunrise to sunset, the indices being set and read at sunrise and read again at sunset, till February 19, and about midnight, Washington time, until May 14, when, the sun being continually above the horizon, they were set at local midnight and read at Washington midnight. This was continued till the closing of the station."

It is difficult to evaluate the results of Lt. Ray's measurements made with the Marie-Davy's conjugate thermometers. Their existence potentially provides our longest baseline of solar radiation observations, although the sensitivity and accuracy of the thermometers may not afford statistically significant conclusions. During the expedition they also proposed to use two pairs of Violle's conjugate thermometers, although it does not appear these instruments were actually deployed.

In July 1951, the Weather Bureau (now the National Weather Service) established a pyranometer at its observing site. These data have been published on a regular basis since then. Again calibration problems made data interpretation difficult. Since then, various researchers have periodically measured solar radiation. Among these were Kelly et al. (1964), Kelley and Weaver (1969), Lieske and Bailey (1963), Lieske and Strochein (1968), Strochein (1965), and Weaver (1969) of the University of Washington, and Thornwaite and Mather (1956, 1958), Weller et al. (1972), Horvath and Brown (1971), and Brown and Johnson (1965).

Most recently the Smithsonian Biological Radiation Laboratory has been conducting pyranometer measurements, using Eppley Model 2 pyranometers. The broad-band filters include cut offs at 290 nm (white glass), 400 nm (green glass), 610 nm (red glass), 715 nm (red glass), and 805 nm (red glass).

South Pole. The South Pole has an extremely uniform snowcover surrounding the station year round. Because the pole has only 1 day (and only one night) per year, and the atmosphere is very clean, and because rather long paths in the atmosphere are viewed by the pyrheliometers; this station may prove to be the most sensitive indicator of climatic change caused by solar radiation variations.

As at MLO, observations of solar radiation began at the South Pole during IGY. Instruments used were Eppley Model 15 pyranometers, one facing up and one facing down for albedo measurements; an Eppley NIP; and a Funk net radiometer. Some of the measurements are summarized by Viebrock and Flowers (1968) and Flowers and Viebrock (1967). Other reports of solar radiation measured at the South Pole include those of Kuhn (1972 and Hoinkes (1960).

American Samoa. American Samoa with its wet and dry seasons should have a marked seasonal variation in solar radiation. The only previous solar radiation observations in Samoa are apparently those of Thompson (1927), who used a Gorczynski pyrheliometer.

4.4.2 New Field Instrumentation

In 1972, MLO acquired a new multichannel pryheliometer (fig. 35) from the National Air Pollution Control Administration (NAPCA), Durham, North Carolina. Furthermore five Eppley Model 2 pyranometers and two UV radiometers arrived, along with a data acquisition system. These radiometers are to improve the quality of solar radiation measurements at MLO.

Table 14 gives the characteristics of the 13-channel thermopile type radiometer as originally calibrated in 1969, and table 15 gives an updated calibration of this instrument done June 16, 1971, by the Eppley Laboratory.

While possessed by NAPCA (before the 1971 calibration), the instrument was damaged by water. As a result, all the interference filters and the two thermopiles in the quartz channels were replaced. The old and new calibrations and filter transmittances given by the manufacturer remain uncertain and have complicated the analysis of observational data obtained with the radiometers. The original aperature on the instrument was 10.5°, but this has been reduced to 5° with a new aperature plate.

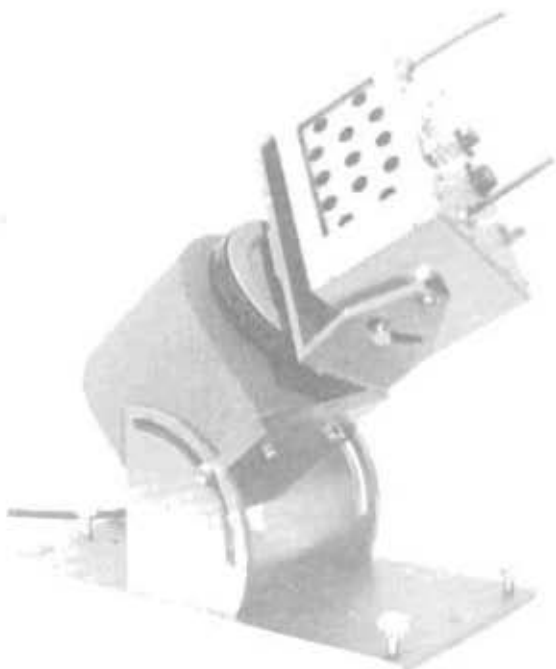

Figure 35. Multichannel radiometer 4202.

Table 14. Channel Characteristics for 13 Channel Radiometer December 1969

Channel No.	Thermopile Serial No.	Resistance Ω	Sensitivity mV/mW cm^{-2}	Filter Limits (set #1) nm
1	10205 G3	636	0.253	285-380
2	10206 G3	638	0.292	390-450
3	10207 G3	587	0.295	445-510
4	10208 G3	633	0.269	495-555
5	10209 G3	605	0.254	552-602
6	10210 G3	611	0.292	600-700
7	10211 G3	629	0.279	650-1040
8	10212 G3	462	0.289	1100-1950
9	10213 G3	610	0.0721	GG22 cutoff 390nm
10	10214 G3	582	0.0619	OG1 cutoff 530nm
11	10215 G3	626	0.0725	RG8 cutoff 695nm
12	10216 G3	603	0.0701	Quartz
13	10217 G3	475	0.0693	Quartz

The thermopiles were calibrated by Eppley Laboratories using quartz filters in place of the narrowband filters. The whereabouts and ownership of these calibration filters is presently unknown. Action is underway to resolve these unknowns.

The characteristics of the Eppley Model 2 pyranometers (table 16) and the two UV radiometers (table 17) are given except for filter transmittance curves which are not included because of the present uncertainties in their values. Both of these sets of data were determined by Eppley Laboratories in December 1969.

Table 15. Channel Characteristics for 13 Channel Radiometer June 1971

Channel No.	Thermopile Serial No.	Resistance Ω	Sensitivity mV/mW cm^{-2}	Filter Limits (set #1) nm
1	10205 G3	636	0.255	270-385
2	10206 G3	638	0.296	385-465
3	10207 G3	587	0.296	455-510
4	10208 G3	633	0.285	495-560
5	10209 G3	605	0.255	550-620
6	10210 G3	611	0.296	612-695
7	10211 G3	629	0.290	650-1045
8	10212 G3	462	0.295	1100-2050
9	10213 G3	610	0.0728	GG22
10	10214 G3	582	0.0625	OG1
11	10215 G3	626	0.0723	R68
12	11132 G3	591	0.0698	Quartz
13	11131 G3	487	0.0693	Quartz

Table 16. Pyranometer Characteristics

Serial No.	Sensitivity mV/mW cm^{-2}	Resistance Ω	Hemisphere	
			Inner	Outer
10151 F4	0.0695	400	WG7	GG22
10152 F4	0.0735	390	WG7	OG1
10153 F4	0.0767	375	WG7	RG8
10154 F4	0.0578	300	Q	Q
10155 F4	0.0711	395	Q	Q

Finally, much of 1972 was spent in devising specifications for new multichannel radiometers and calibration equipment to be procured. Discussion of this material will be presented in the next annual report.

Table 17. UV Radiometer Characteristics

Serial No.	Sensitivity mV/mW cm^{-2}
10232	1.91
10233	2.17

4.4.3 Calibration Equipment

At MLO we have an Angstrom compensation pyrheliometer No. 10180 and Eppley control unit No. 4142. The other standard instrument is the Eppley Model 2 pyranometer No. 10155F4 which was used in an international comparison of pyranometers in May 1971 (Thekaekara et al., 1972). The Angstrom pyrheliometer was also used in instrument comparison tests at Table Mountain, California, in October 1972 (Willson, 1972). Both standards have been calibrated relative to the International Pyrheliometric Scale (IPS).

The pyrheliometers are calibrated by simultaneously making side-by-side comparisons of the standard and field instruments using the sun as a source. Pyranometers are calibrated either by using a standard pyrheliometer and a shading disk with the sun and sky as a source, or by comparing it with a standard pyranometer that was calibrated by using a shading disk. Two pyranometers may be compared using either the sun and sky as a source or an integrating sphere.

A more detailed description of the calibration and quality control will be given in the next annual report when a more complete set of calibration and test equipment will be available.

4.4.4 Data Summary

The daily total horizontal incidence radiation data is shown in tables 18 and 19.

4.5 Cooperative Programs

4.5.1 Measurement of Sr^{90}

A cooperative program with AEC is the Funnel Ion Exchange Column Fallout Collector. This column is manned by the MLO staff and sent in to AEC once a month.

The ion exchange collector measures fallout at sites removed from nuclear tests. The collectors are exposed for monthly intervals and the collected fallout is shipped to New York for analysis. The instrument consists of a funnel, an ion exchange column, and a leveling device — all constructed of polyethylene — mounted in a wooden housing. The ion exchange column is packed with paper pulp and is saturated with water. Insoluble material is filtered on the paper pulp and soluble substances are absorbed on the resin. The collector is situated to receive precipitation in an open area free of any obstructions that might shelter it.

4.5.2 Total Surface Particulate Matter (EPA)

The High Volume Air Samplers (hi vol sampler) uses a vacuum-cleaner type motor-and-blower to draw large volumes of air through a filter and collect particulates for measurement and analysis. When in use, the sampler is enclosed in a shelter that permits air to enter, but also protects the instrument from weather, mechanical hazards, coarse matter, and trash.

The filters that collect the suspended particulate matter from the hi vol samplers are sent to the Environmental Protection Agency (EPA) bi-weekly on the same schedule as that for the SO_2 samplings. One sampler is located at MLO and the other is at the Hilo Offices.

4.5.3 Total Surface Particulate Matter (AEC)

Filters for the Atomic Energy Commission (AEC) hi vol are sent to AEC's Health and Safety Laboratory in New York City four times a month. This sampler, located at MLO, was originally set up to measure radioactive fallout. Lately their program is being expanded into more general environmental activities and study elements other than the radioactive ones. Specifically, the AEC has been concentrating on lead analyses.

4.5.4 Surface Tritium Concentration

The University of Miami program, measures HTO and HT surface concentration.

4.5.5 Condensation Nuclei Concentrations

The State University of New York program measures surface condensation nuclei concentration with a Pollak counter.

4.5.6 *Surface SO_2 and NO_2*

SO_2 gas samplings are taken for EPA bi-weekly and sent to the National Air Surveillance Networks (NASN). One gas sampler is located at MLO and the other at the Hilo Office. The number of sampling trains has been increased from three to five since October 24, 1972.

The multiple gas sampling system consists of a collecting unit and a vacuum pump. The collecting unit is a box that houses five individual bubbler trains operating in parallel between inlet and outlet manifolds; this makes it possible to sample continuously and concurrently over a 24 hour period at MLO for a maximum of five different gaseous pollutants. A prefilter removes suspended particulate matter from the air during sampling. The gas sampler and pump are indoors (or in a shelter); the outside ambient air is drawn in through a probe extending out a window or other opening. Bubblers filled with collecting reagents are sent to the sampling stations by the NASN Laboratory in advance. After collection, the samples are returned to the laboratory for analysis.

4.5.7 *Precipitation Collection for Chemical Analysis*

Although not in operation at the end of 1972, an EPA collector has been installed at MLO. Precipitation collected will be sent for analysis to the EPA Laboratory in Rayleigh, N.C.

4.5.8 *Fog Concentration*

A cooperative program with the University of Hawaii in Hilo has been established to measure fog concentration at MLO.

4.5.9 *Atmospheric Extinction*

Spectral extinction coefficients are measured at MLO for Air Force Cambridge Research Lab (AFCRL).

5. DATA ACQUISITION SYSTEM

5.1 Requirements

The list of sensors and instrumentation in section 3 clearly illustrates the variety of signals, sampling rates, and control functions that must be handled at the monitoring observatories. Two distinct cases present themselves in manipulating the data. First the reduction of signals so useful data can be obtained (gas and aerosol sampling in particular) by applying calibration constants and standard statistics to derive

Table 18. MLO Total Daily Insolation (langleys) for 1971

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	486	372	632	285	501	419	484	727	591	422	533	446
2	497	293	543	289	584	434	556	729	669	594	535	464
3	487	498	601	255	734	633	733	724	680	681	399	344
4	494	467	629	278	739	609	734	713	688	628	306	446
5	348	543	646	212	487	723	689	443	693	619	309	400
6	363	564	326	279	549	681	731	269	695	488	409	258
7	485	569	588	513	456	715	755	363	677	596	397	380
8	491	583	645	418	508	743	741	465	677	548	514	438
9	127	577	648	620	541	745	579	490	586	605	525	429
10	417	577	648	707	691	744	365	577	679	509	526	471
11	243	567	693	554	736	729	645	708	619	598	535	471
12	355	577	657	601	735	729	451	724	569	550	558	469
13	353	587	641	704	608	611	584	555	646	581	509	351
14	447	589	613	347	736	727	281	641	525	588	435	333
15	342	605	669	326	649	495	356	707	663	593	517	335
16	-	595	670	326	601	511	499	685	493	508	469	318
17	480	620	673	433	650	716	479	455	342	426	363	395
18	306	628	601	389	412	711	725	430	228	363	451	268
19	205	628	656	311	617	730	727	702	477	534	461	-
20	267	622	514	279	653	735	719	684	544	480	515	545
21	551	539	275	301	633	728	732	708	223	565	500	465
22	509	642	483	198	618	732	719	712	656	475	466	408
23	525	566	558	166	740	733	729	516	526	450	236	342
24	476	393	488	229	746	730	723	521	388	566	165	384
25	453	520	338	261	742	690	661	537	332	561	100	437
26	555	474	544	280	734	733	716	674	194	394	473	462
27	400	635	526	439	741	736	722	694	329	324	497	460
28	178	608	521	613	614	561	660	698	565	339	494	458
29	516	-	409	659	407	431	724	669	575	148	326	252
30	512	-	287	352	363	409	701	370	304	212	205	233
31	357	-	272	-	365	-	723	688	-	533	-	262

Table 19. MLO Total Daily Insolation (langleys) for 1972

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	266	541	585	363	645	601	513	693	403	531	537	463
2	236	504	580	172	527	470	489	644	560	600	501	479
3	233	292	472	365	309	566	697	677	658	343	511	475
4	404	421	451	222	490	485	700	556	439	240	503	466
5	463	524	504	518	478	499	680	450	665	481	503	460
6	399	291	149	202	498	256	510	430	597	356	484	446
7	356	186	594	501	367	355	468	629	-	319	350	458
8	407	408	613	391	400	336	403	611	387	495	492	461
9	474	327	617	361	374	319	229	695	375	560	507	403
10	470	259	397	686	346	406	287	562	353	532	448	373
11	474	546	534	672	425	380	484	337	355	549	421	478
12	326	238	453	529	556	656	673	491	433	607	455	425
13	330	523	392	526	168	715	698	680	521	304	455	459
14	165	567	512	400	261	622	589	678	346	294	315	375
15	231	584	595	195	349	721	317	652	-	336	493	119
16	297	569	638	213	636	609	286	439	627	447	480	460
17	416	578	651	386	674	732	303	701	621	556	276	453
18	487	562	649	380	721	482	419	295	544	541	401	369
19	501	546	662	605	729	376	343	-	631	525	491	292
20	498	509	653	662	726	669	437	-	623	569	480	463
21	297	439	645	600	544	429	434	310	626	565	482	468
22	432	451	555	639	544	412	632	543	623	563	483	408
23	291	386	660	607	501	623	695	495	509	551	492	411
24	330	358	643	696	415	598	697	552	401	560	486	443
24	509	239	656	688	284	696	596	625	347	528	456	451
26	518	601	624	670	643	530	381	662	586	389	486	458
27	230	595	659	706	715	698	494	521	622	508	463	465
28	174	523	325	564	715	688	698	487	626	493	445	463
29	155	609	165	484	471	480	703	437	581	344	471	465
30	539	-	703	367	685	371	562	551	416	235	459	457
31	538	-	690	-	595	-	673	183	-	211	-	456

means and variances. Second, indirect sensors such as the Dobson spectrophotometer and the lidar instruments require considerable computer processing of the signals. The degree to which these computations depend on access to large calibration tables makes it impractical to consider that "stand-alone" computer systems at the stations could handle the task. Furthermore, the generally "remote" nature of the observatories and the number of signals involved make the use of time-share computer systems difficult. A signal acquisition system must therefore be able to convert many channels of analog voltages into digital form, and then record these signals along with related digital data on magnetic tape in a computer-compatible format. A real-time operating routine will be used for this. Magnetic tape will therefore serve as the primary medium for transferring and storing data.

The sampling interval is dictated by the sensor with the shortest response period; at this time, this is the multichannel pyrheliometer with a response time slightly larger than 1-sec. If a need for statistics based on data of this resolution can be demonstrated, a computational program will be written to provide them. Otherwise, in the initial phases of software development an 8-sec integral value of all signals will be recorded on tape. In this way, a 10-inch reel of tape will last 7 to 10 days. In addition, control and calibration pulses must be started or set by the signal acquisition process if signals are to be introduced properly. Performance of this combination of tasks in a real-time operating mode along with the computation of summary statistics requires the use of a small dedicated minicomputer. To fulfill the above requirements, we are working on assembling a signal acquisition system, diagrammed in figure 36 for use at the monitoring station.

5.2 Hardware Development

At this time, six of the components represented in figure 36 have been purchased and are being evaluated in the Techniques and Standards Group. They are an analog-to-digital converter (Xerox Data System, Model 40) with 32 differential input capacity and programmable gain and a minicomputer (Data General Corp., NOVA 1220) with a 1.2 μsec memory access time and memory capacity of 8146, 16-bit computer words. The system also contains a teletype with a paper tape reader and punch to control the minicomputer. The two major output devices are 24-point analog recorder (Leed and Northrup, Speedomax G) and a magnetic tape drive (Wangco, Mod-10) that records at 800 characters/inch (nine track, NRZ1), at 45 inches/sec. Interfacing electronics between the analog-to-digital converter (Morgan Assoc.) and the teletype and tape drive (both by Data General Corp.) are now being tested. An external clock (Sierra Research Corp.) that counts and displays days-of-the-year, hours, minutes, and seconds, has been successfully interfaced with the minicomputer. The preamplifiers, with voltage calibration facility, and a digital input and output interface are yet to be constructed.

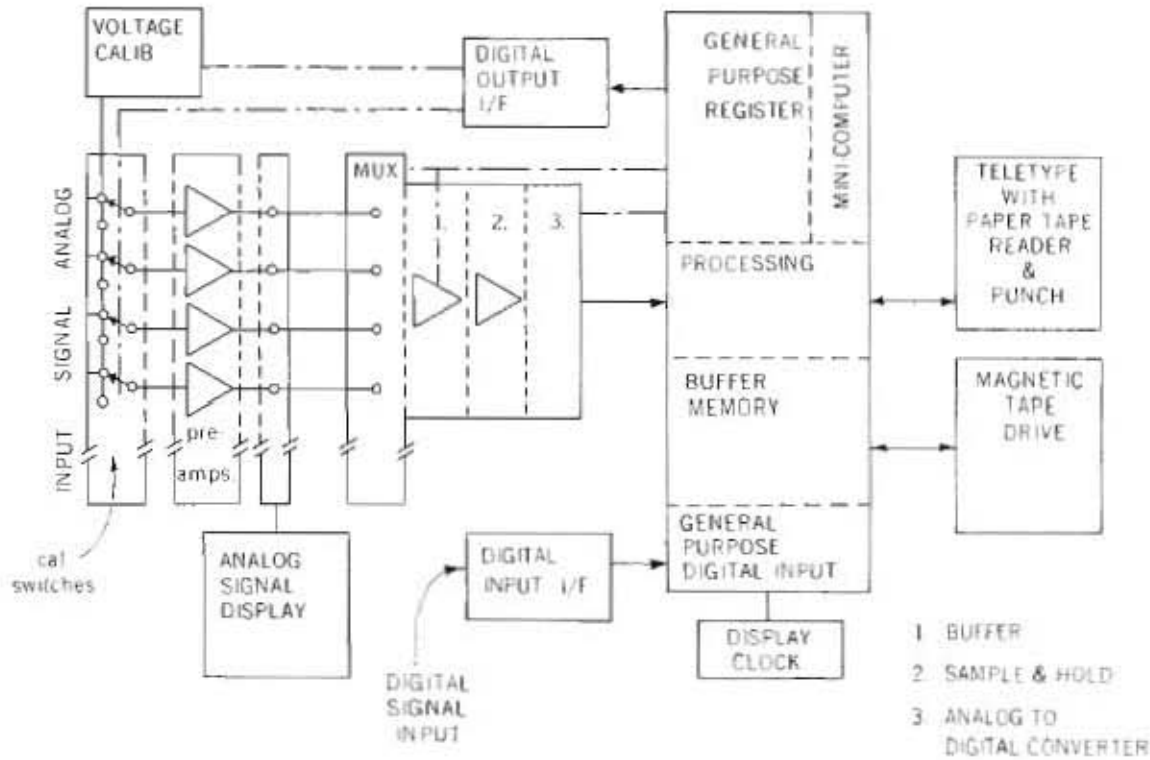

Figure 36. Schematic of hardware system.

5.3 Software Development

In the early stages of development, the many software problems have been taxing. All diagnostics provided with the minicomputer and the peripherials were tested during the warranty period. In this period a bootstrap loader was written to transfer core images between the central processor and the magnetic tape drive; this made possible the storing of bulk programs on magnetic tape in addition to punched paper tape. This procedure considerably speeds program transfer. Work was also started on a series of subroutines in assembly language to control the peripheral devices. The controller for the Mox-A/D was acquired from the Cryogenics Division, National Bureau of Standards (NBS) (275.00) along with an operating or executive system written in BASIC will call subroutines. Routines to read and set the display clock have also been written and tested. The two major tasks remaining are converting this "stand-alone" BASIC into a real time operating system, and generating a flexible tape drive controller.

6. REGIONAL STATIONS

Besides the baseline stations described in this report, there are 10 WMO-designated regional stations in the United States. This network is administrated and operated by the NOAA-NWS in cooperation with the EPA and is a complimentary system to the baseline network.

At these stations (table 20 and fig. 37) two measurements are made: turbidity and precipitation chemistry. The turbidity is measured by a dual wavelength (380 and 500 nm) Eppley Model DA Sunphotometer (fig. 38). The instrument is described in the WMO Operating Manual for Sampling and Analysis Techniques for Chemical Constituents in Air and Precipitation (World Meteorological Organization Report No. 299, Geneva, Switzerland). In figure 39, the instrument which is used to collect the precipitation for chemical analysis is shown. The EPA Laboratory in Raleigh, N.C., analyses the precipitation for those components listed in table 21.

The only published measurements to date are contained in the first volume of the turbidity data in *Atmospheric Turbidity Data for the World*, July-December 1971. Yearly publication of the turbidity values will continue under the sponsorship of the WMO. Plans are to begin the publication of precipitation chemistry data in 1973.

Table 20. WMO-Designated Turbidity and Precipitation Sampling Network (NWS/EPA)

(1)	Alamosa, Colorado	(6)	Meridian, Mississippi
(2)	Atlantic City, New Jersey	(7)	Pendleton, Oregon
(3)	Bishop, California	(8)	Raleigh, North Carolina
(4)	Caribou, Maine	(9)	Salem, Illinois
(5)	Huron, South Dakota	(10)	Victoria, Texas

Other Stations Where Rainwater is Aiso Collected (EPA)

(1)	Cherokee County, Oklahoma	(5)	Grand Canyon, Arizona
(2)	Cumberland County, Tennessee	(6)	Hardee County, Florida
(3)	Door County, Wisconsin	(7)	Tom Green County, Texas
(4)	Glacier Park, Montana		

Figure 37. Atmospheric turbidity and precipitation sampling network.

7. RESEARCH SUMMARY

7.1 1970-72 Publications Related to the Operation of Mauna Loa Observatory

E. W. Barrett, R. F. Pueschel, P. M. Kuhn, and H. K. Weickmann

Inadvertant Modification of Weather and Climate by Atmospheric Pollutants, ESSA Tech. Rept. ERL 185-APCL 15, Sept. 1970.

J. F. S. Chin, H. T. Ellis, B. G. Mendonca, R. F. Pueschel, and H. J. Simpson

Geophysical Monitoring at Mauna Loa Observatory, NOAA Tech. Memo. ERL APCL-13, July 1971.

Figure 38. U.S. sunphotometer.

Figure 39. Precipitation chemistry collector.

Table 21. Quantities Measured

(1)	pH	(11)	F^-
(2)	Conductivity	(12)	NH_4^+
(3)	Acidity	(13)	Cd^{++}
(4)	Ca^{++}	(14)	Pb^{++}
(5)	K^+	(15)	Zn^{++}
(6)	Mg^{++}	(16)	Cu^{++}
(7)	Na^+	(17)	Fe^{++}
(8)	$SO_4^=$	(18)	Mn^{++}
(9)	NO_3^-	(19)	Ni^{++}
(10)	Cl^-		

H. T. Ellis and R. F. Pueschel

Solar Radiation: Absence of Air Pollution Trends on Mauna Loa, *Science 172*, 845, 1971.

H. W. Ellsaesser, R. F. Pueschel, and H. T. Ellis

Turbidity of the Atmosphere: Source of Its Background Variation with the Season, *Science 176*, 814, 1972.

R. F. Pueschel and B. G. Mendonca

Sources of Atmospheric Particulate Matter in Hawaii, *Tellus* May 1972.

H. J. Simpson

The Cation Content of the Hawaiian Atmosphere, *J.G.R.* August 1972.

B. A. Bodhaine and R. F. Pueschel

Flame Photometric Analysis of the Transport of Sea Salt Particles, *J.G.R.* August 1972.

R. F. Pueschel and B. G. Mendonca

Dispersion into the Higher Atmosphere of Effluents during an Eruption of Kilauea Volcano, *J. Rech. Atm.*, to be published.

B. G. Mendonca and R. F. Pueschel

Ice Nuclei, Total Aerosol and Climatology at Mauna Loa, Hawaii, *J. Appl. Met.*, 12(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.*, 12(2):308-315, 1973.

R. F. Pueschel, H. T. Ellis, G. E. Cotton, L. Machta, E. C. Flowers, and J. T. Peterson

Normal Incidence Solar Radiation at Mauna Loa, Hawaii, *Nature*, to be submitted.

G. Langer, R. F. Pueschel, B. G. Mendonca, and C. J. Garcia

Inventory of Ice and Condensation Nuclei on Hawaii, *Tellus*, to be submitted.

H. T. Ellis, C. J. Garcia, R. T. Hansen, and R. F. Pueschel

The Influence of Atmospheric Precipitable Water and Local Volcanic Effluents upon Solar Radiation Measurements at Mauna Loa, *J. Atm. Sci.*, to be submitted.

7.2 Geophysical Monitoring Techniques and Standards Group

W. D. Komhyr, E. W. Barrett, G. Slocum, and H. K. Weickmann

Atmospheric Total Ozone Increase During the 1960's, *Nature 232*, August 1971.

W. D. Komhyr and R. D. Grass

Dobson Ozone Spectrophotometer Modification, *JAM 11*, 1972.

7.3 Air Resources Laboratories

L. Machta

Mauna Loa and Global Trends in Air Quality, *BANS 53*, 1972.

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

Rudolf F. Pueschel, Director and Supervisory Physicist
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, NRC Resident Research Associate
Mark A. Goldman, Presidential Intern
Judith B. Pereira, Secretary
Marge K. Kealanahele, Temporary 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

V. Rumble, Physicist

8.4 GMCC Staff

Donald H. Pack, Director, GMCC
Gerald F. Cotton, Statistician
Charles P. Turner, Technical Assistant to the Director
John M. Miller, Research Meteorologist

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APPENDIX A: Computer Program for LIDAR Computations

```
*NAME   LIDAR
        DIMENSION Y(50,20), HL(50), YM(50), SYM(50)
        READ(8,5) NS, NL, NH
     5  FORMAT(2I3, F6.2)
        READ(8,10) (HL(I), I=1, NL)
    10  FORMAT(16F5.1)
        PAV=0.0
        DO 500 J=1, NS
        READ(8,15) P, A, B, BW1
    15  FORMAT(F6.3, 2F5.2)
        PAV=PAV+P/NS
        ZOF=(A+B-BW1)/2.
        DO 100, I=1, NL
        READ(8,20) BW, YMAX, YMIN
    20  FORMAT(F4.1, 2F5.1)
   100  Y(I,1)=((YMAX+YMIN-BW)/2.-ZOF)/P
        DO 200 I=1, NL
   200  Y(I,J)=Y(I,J)*HL(I)/HL(1)*HL(I)/HL(1)
   500  CONTINUE
        DO 1000 I=1, NL
        SUMY=0
        SUMSQ=0
        DO 900 J=1, NS
        SUMY=SUMY+Y(I,J)
   900  SUMSQ-SUMSQ+Y(I,J)*Y(I,J)
        YM(1)=SUMY/NS
        SYM(I)=SQRT((SUMSQ-NS*YM(I)112)/(NS*(NS-1)))
  1000  HL(I)=HL(I)+SH
        READ(8,25) MO, KDAY, KYR, KTIME
    25  FORMAT(3I3, I5)
        WRITE(5,30) MO, KDAY, KYR, KTIME
    30  FORMAT(1H1,40X'EVALUATION OF LIDAR DATA'/50X'DATE'1X,I2,'/',
       1 '/'I2,/50X'TIME'1X,I4,1X'HST'//20X'HEIGHT'10X'BACKSCATTERING
       2 FUNCTION'5X'STANDARD'/22X'KM'16X'ARBITRARY UNITS'9X'DEVIATION'/
        DO 1500 I=1, NL
  1500  WRITE(5,35)HL(I), YM(I), SYM(I)
    35  FORMAT(F26.2, F22.3, F24.3)
        WRITE(5,40) NS, PAV
    40  FORMAT(1HO, 40X'NUMBER OF SHOTS IS',13,10X'AVE POWER IS',F10.3)
        CALL EXIT
        END
```

APPENDIX B: MLO Selected Monthly Measurements
of Aitken Particles by a Gardner Counter
1971-1972

January 1971

Date	A.M. 9	10	11	Noon	P.M. 1	2	3
4	350	400	900	1300	2000	1300	
6	700	360		(45 mph blo. snow)			
8	200	125	300	700	120	320	
11	200	150	<100	1100	<100	<100	
13	300	<100	230	200	150		
15	375	900	200	150	<100		
18	400	200	150	200	300	200	
25	400	200	200	350	900	1100	
27		220	100			160	150

April 1971

Date	A.M. 9	10	11	Noon	P.M. 1	2	3
7		250	300	560	570	690	460[1]
12	150	200	200	450	300	250	400
14		380	400	660		630	1100[2]
16	250	360	600	360	500	250	
19	400	400	550	600	600	550	
21	460	430	520	380	690	690	730[3]
23	100	200	200	1500	1200	3500	300
26	200	150	400	300	300		
27				400			
28	240	300	230	250	350	280	
30	200	200	350	500	350	300	

[1] charge battery.
[2] hail 1200-1400.
[3] fog 1200.

July 1971

Date	8	A.M. 9	10	11	Noon	P.M. 1	2	3
2	900	700	500	500	400	300	400	150
3						250		320
4	200			300			3000	
6			700	600	400	300		
7		280	310	250	300	270	230	
9		400	800	400	1000	200	100	
12		700	500	600	300	250	100	
14	200	200	150	150	800	1000	980	(fog)
16		600	400	500	300	200		
19			500	300	400	300		
20				350			400	250
23	800	800	400	300	300	300	150	150
26			220	250	1700	800	1200	
28		340	360	210	250	680	300	300

November 1971

Date	A.M.					P.M.			
	7	8	9	10	11	Noon	1	2	3
1			300	300	350	400	400	350	300
2	300	300	300	300	300	250	350		
3			300	320	300	350	400	450	
4		290	475	450	350				
5		250	300	450	475	450		520	650
8		300	350	400	280	290			310
9			300	350	400	550	500	900	1000
10				550		500		500	1500
11				300		800	400		
12					280	215		450	
14		850				450		250	
15				150	300	150	300		550
16		100	<100	<100	170		680	570	
17		(Drizzle)	150	120	150	700	700	300	500
18			150	150	150	400	200	200	
19			150	150	200	200	300	250	100
22			250	300	350	350	700	450	
23			200		200	530		1200	
24		200	170	290	220		150		
26			200	200	250	300	150	200	
29		(Blowing mist)	290	175	170	220	800	875	860
30			150	300	300	150	250	150	200

January 1972

Date	A.M.					P.M.			
	8	9	10	11	Noon	1	2	3	4
3		150	150	200	250	500	500		
4	300	250	450	450		570		350	450
5		350	300	200	300	250	350		
6		300	250	300	300	450	400		
7	230	230	220	290		370	240		
9		560	350					700	3000
10		200	300	300	250				
11		150	100	150	150	100	125		
12		160	230	160	560	900	1300		
13		300	300	300	350	300	400	350	
14		250	300	350	900	1000	900		
17		280	450	370		300	450		
18		350	450	500	450	300	200	350	
19		200	200	250	300	300	500		
20	270	280	200	400	360	770	2100		
21		250	250	550	<200	1900	2200	2000	1800
24		200	200	150	200	150	150		
25		250	290	230	230	280	290		
26		200	300	200	300	250	450		
27		200	200	300	150	200	200		
28		230	290	220	250	290	230		
31		150	150	200	250	250	300		

April 1972

Date	A.M.					P.M.					
	7	8	9	10	11	Noon	1	2	3	4	5
3			180	580	460	800	690	460			
4			450	550	550	400	370	250	<200		
5			150	200	300	400	300	300			
6	(fog/drizzle all day)		150	590	240	<150	290	590			
7			370	350	300	300	600	520			
10			300	300	400	300	300	410			
11		580	680	680	680	690	510	530	680		
12			1200	350	300	200	450	600			
13			300	350	400	600	600	450			
14			280	590	900	1200	1200		950		
18					680	350	450	700			200
19	400	370-400	680	400	560	680			730		
20			200	250	250	300	450	450			
21			200	250	300	300	200	250			
24			230	580	240	300	320	450	680		
25			350	1100	370				600		
26				360		580	580	455			
27			370	380	500	725	1200	1400	1000		
28			300	300	360	450	450	800	1400		

July 1972

Date	A.M.			P.M.			
	9	10	11	Noon	1	2	3
3	230	240	250	300	1130	1200	
5	300	350	250	100	330	500	
6	265	300	250	260	240	300	
7		270	170	240	240		
8	185	185	185	185	185	185	
11	230	680	180	180	185	170	
12	270	210	1700	200	220	100	
13	80	80	80	80	80	125	
14	150	100	100	100	290	560	
17	200	250	250	200	150	300	
18	165	165	165	930	240	170	
19	100	190	215	140	140	190	
20	150	<150	200	250	250	300	250
21	240	240	240	240	240	290	
24	170	240	180	250	140	140	
25	150	200	150	150	150	240	
26	140	140	140	140	150	300	
27	130	100	<100	140	330	<100	
28	200	<150	<100	160			
31	150	200	150	160	140	100	

[1] upslope 1300. [2] upslope 1200. [3] rain 1330.

November 1972

Date	A.M.			Noon	P.M.		
	9	10	11		1	2	3
1	200	300	300	500	500	400	
2	<140	350			300	290	
3	600	600	600	600	600	600	600
6	180	180	210	200	280	1020	
7	200	300	500	400	550	300	
8			380	340	250	300	300
9	300	400	350	250	560	300	
10	<140	780	2500	3700	1500	560	
13	700	700	700	700	700	700	
14	650	500	300	300	500	700	
15	<140	240	250	260	340	350	
16	<140	<140	600	600	600	600	
17	<140	140	680	440	420	920	
20	400	400	500	600	400	450	
21	700	700	300	300	330	700	
22	520	2550	740	350	450	360	
24	200	200	500	200	400	950	
27		200	300	300	400	350	
28	200	300	300	400	400	900	
29	400	380	310	370	310	310	
30	250	300	350	400	300	200	

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