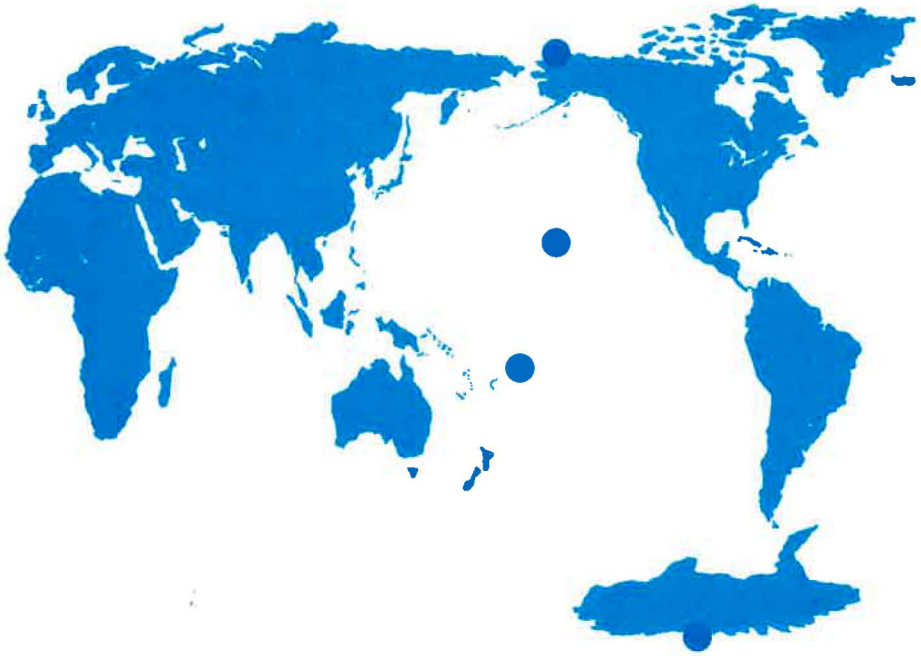
Geophysical Monitoring for Climatic Change

No. 4

Summary Report 1975



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GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE NO. 4

SUMMARY REPORT - 1975

James A. Watkins, Editor

BOULDER, COLO.
August 1976

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1. SUMMARY

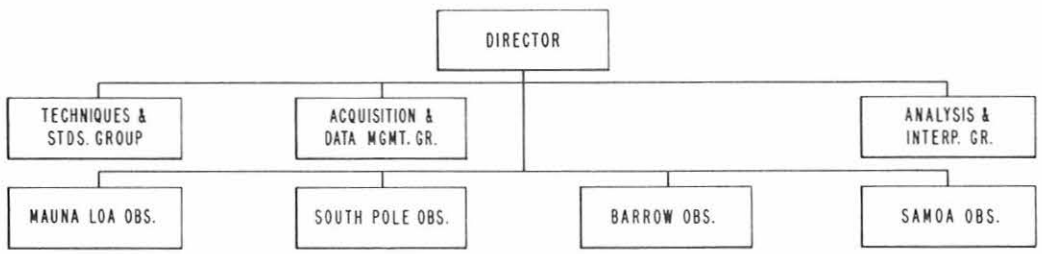
The highlight of 1975 was the completion of the fourth GMCC Observatory at American Samoa. This is the final baseline-type observatory in present planning; future effort will concentrate on bringing full program levels to these four observatories.

The National Science Foundation opened the new South Pole Station in early 1975 and closed the old Station that was built in 1957. The new station location (about 1 km away) necessitated relocation of the GMCC program. For this purpose a small temporary building was constructed and placed just below the snow surface about 120 meters upwind of the new Station. This served the GMCC program adequately during 1975. A more permanent above-the-snow structure is being planned by NSF and NOAA for construction during the 1976-77 austral summer season.

Automatic data acquisition systems (ICDAS) have been installed at all four GMCC Observatories. These systems log the data on magnetic tapes which are shipped to the GMCC offices in Boulder for processing. In the area of measurement techniques, noteworthy accomplishments were (1) the development of a "through-the-analyzer" flask exposure system and (2) the acquisition of three nephelometers to complete the requirements for such measurements at the four observatories.

In July 1975, Mr. Donald Pack, Director of the GMCC Program since its inception, retired. His many friends and associates in the Program take this means of expressing their sincere thanks for all he has done over the years (71-75) to guide this Program from the dream of long-term monitoring to its present level. These people also wish him the best of health, enjoyment, and satisfaction in the years to come.

A new organization group has been formed, the Data Acquisition and Management Group, to carry out the function of acquiring, processing, and archiving the observatory measurements. Thus, the GMCC now has the following organizational structure with headquarters in Boulder and four observatories.



2. OBSERVATORY FACILITIES

This section documents changes in existing physical facilities or addition of new facilities at the observatories that are relevant to the character and quality of the measurements being made. Simple relocation of monitoring systems or installation of new systems is covered in Section 3.

2.1 Mauna Loa

A small portable trailer was modified during the first quarter of 1975 to temporarily house a portable lidar system being developed for the Barrow Observatory. A shelf and an instrument rack were fabricated and installed in the trailer.

In March, a Telex machine (number 633145) was installed in the Hilo office to provide an alternate means of communication with various stateside offices and to reduce the monthly phone costs.

The Instrument Control and Data Acquisition System (ICDAS) and several major pieces of equipment were damaged during a lightning storm in early December. Although most of the equipment was returned to operation in a relatively short time, the ICDAS remained down until early January 1976, resulting in considerable loss of data. This event emphasizes the need to provide better electrical grounding against lightning strikes for the facilities at Mauna Loa. Possible solutions for this problem will be investigated in 1976.

2.2 Barrow

Several facility improvements were made to the Barrow Observatory during 1975. A power cable was installed to the 17-meter meteorological sampling tower NE of the station. Several circuits in the main building and the Dobson platform were rewired to provide better power distribution. A 3.6-meter-square wooden sampling platform was constructed and wired for a cooperative Energy Research and Development Agency (ERDA) air sampling program. Access to the roof platform of the main building was improved with the addition of stairs, and two windows were added to provide greater visibility. A new refrigerator/stove/sink unit was put into service and a 94-liter water storage tank was installed. Station security was improved by installation of locks on all doors and floodlights to illuminate the main building during dark periods.

A Bombardier "Bombi", a small, tracked, all-terrain vehicle, arrived in July and provided access to the station during summer thawing and winter storms. A chain gate was placed across the road to deter unauthorized visitors and a sign was constructed to identify the station and its requirement for "clean air" monitoring. As a result of limiting traffic during the summer thaw, the road remained in excellent condition through most of the winter.

Fig. 1 is an aerial view of the Point Barrow complex prior to construction of GMCC station.

Figure 1. Point Barrow complex in 1971. A - Naval Arctic Research Laboratories. B - POW-Main DEW Station (USAF). C - Location of GMCC Observatory (constructed in 1972).

2.3 South Pole

1975 was marked by the long-awaited opening of the new U.S. South Pole Station with its 16-meter-high aluminum geodesic dome, after nearly four austral summers of construction. The new station is approximately a kilometer from the original station that was built during the IGY. On December 14, 1974, radio communications gear was switched to the new station and the first residents moved in. On December 27, the symbolic barber-shop-striped South Pole and surrounding flags of the 18 Antarctic Treaty nations were moved to a spot near the new station entrance. Political leaders, administrators, scientists, and logisticians from the United States and other countries dedicated the new U.S. Amundsen-Scott South Pole Station in ceremonies at the site on January 9, 1975.

The GMCC program was removed from the Aurora Tower at old Pole Station and transferred to a temporary under-snow facility located about 120 meters grid northeast of the sky laboratory in the science quadrant of the new Pole Station (Fig. 2). Constructed of plywood and old shipping crates, this "clean air" facility is to serve as temporary housing for those programs, like GMCC, whose requirements are to monitor atmospheric parameters free from local contamination a majority of the time (figs. 3 and 4). It is intended to last 2 to 3 years while a new, more permanent, structure is designed and built. The structure was trenched below the snow surface to avoid appreciable drifting of snow downwind atop other sensors and equipment located in the science quadrant. Entrance is gained by a 1.5-meter-square vertical shaft located in a corner of the building. The facility has a usable floor area of 47 square meters (504 square feet) of which 34 square meters (360 square feet) are dedicated to GMCC's use.

By mid-January, construction was nearly complete and about 80% of the monitoring programs had been relocated. The aerosol/gas sampling stacks were erected with the help of a crane. The intakes are about 6 meters above the surrounding snow surface and point into the predominant wind direction which is 20° east of grid north. In late January, the skid-mounted Dobson spectrophotometer and ERDA sampling huts were pulled by tractor from their old locations near the Aurora Tower to their new locations near the "clean air" facility and the area around the facility was backfilled with snow. A metal pedestal was fabricated to mount a 13-channel pyrheliometer north of the facility and a 3-meter square wooden platform was constructed to mount other solar radiation sensors. Figure 4 shows the location of the facility relative to surrounding structures and equipment.

By the end of the austral winter, the facility was beginning to show signs of compression due to an increasing snow load on the roof. The ceiling had begun to sag near the center and one support post had cracked. Plans were made to add more support beams for the ceiling and to extend the vertical access shaft by 1 meter during the austral summer.

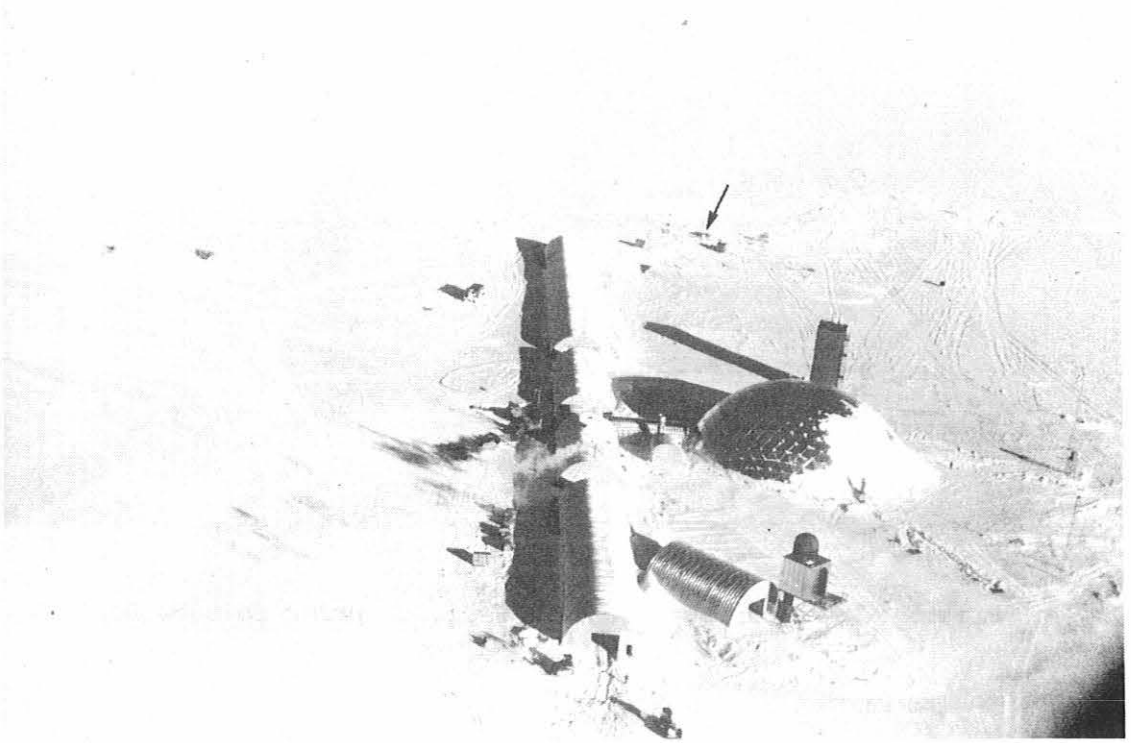


Figure 2. Aerial view of the new South Pole Station, with the "clean air" facility marked.

2.4 Samoa

The GMCC program is greatly indebted to the Government of American Samoa and to High Chief Iuli Togi for their assistance in establishing the Samoa GMCC Observatory. Construction of the Samoa GMCC Observatory was completed in September 1975. By late December most of the instrumentation and the data acquisition system were installed. On November 27 the Observatory was dedicated in a ceremony attended by the officials of NOAA, the Government of American Samoa, and the local Samoan chiefs and dignitatries (Fig. 6). In January 1976, the Observatory became fully operational.

Access to the observatory is provided by a paved, single-lane road, which ties into the main island road in Tula Village. The road was originally paved in March, but heavy construction traffic damaged much of the surfacing, and repaving was necessary in November. A chain gate was placed across the road to minimize unnecessary traffic and its resulting pollution.

The 27x5 m building (Fig. 7) is located at 170°33'46"W, 14°15'08"S, with an elevation of about 77.4 m above mean sea level. The building is fully air conditioned to protect the computer and instrumentation from rather high ambient humidity. Building water is supplied by a water catchment system. Water is collected on the upper observation deck and stored in a 38-kl underground cistern.

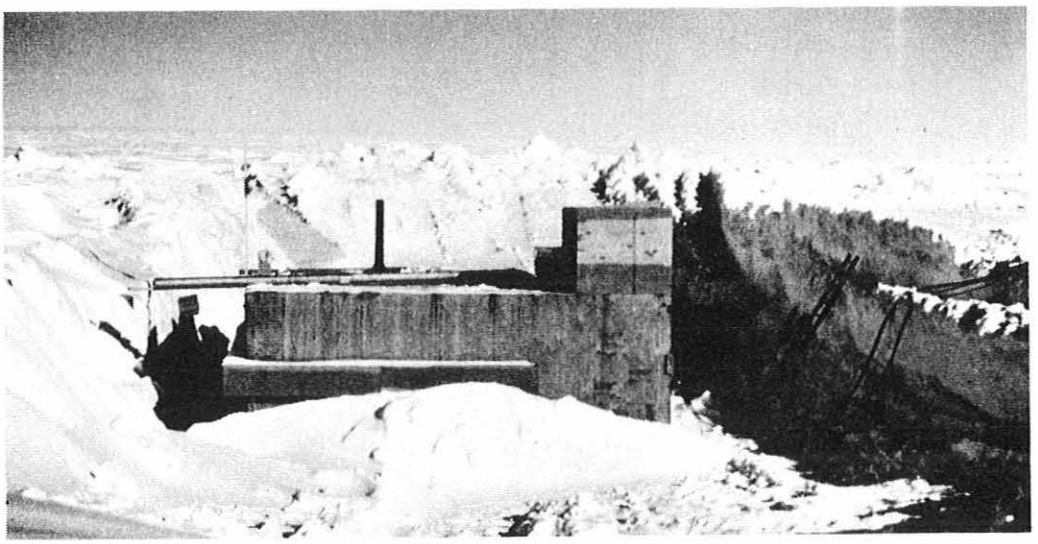


Figure 3. Temporary clean-air facility prior to snow burial.

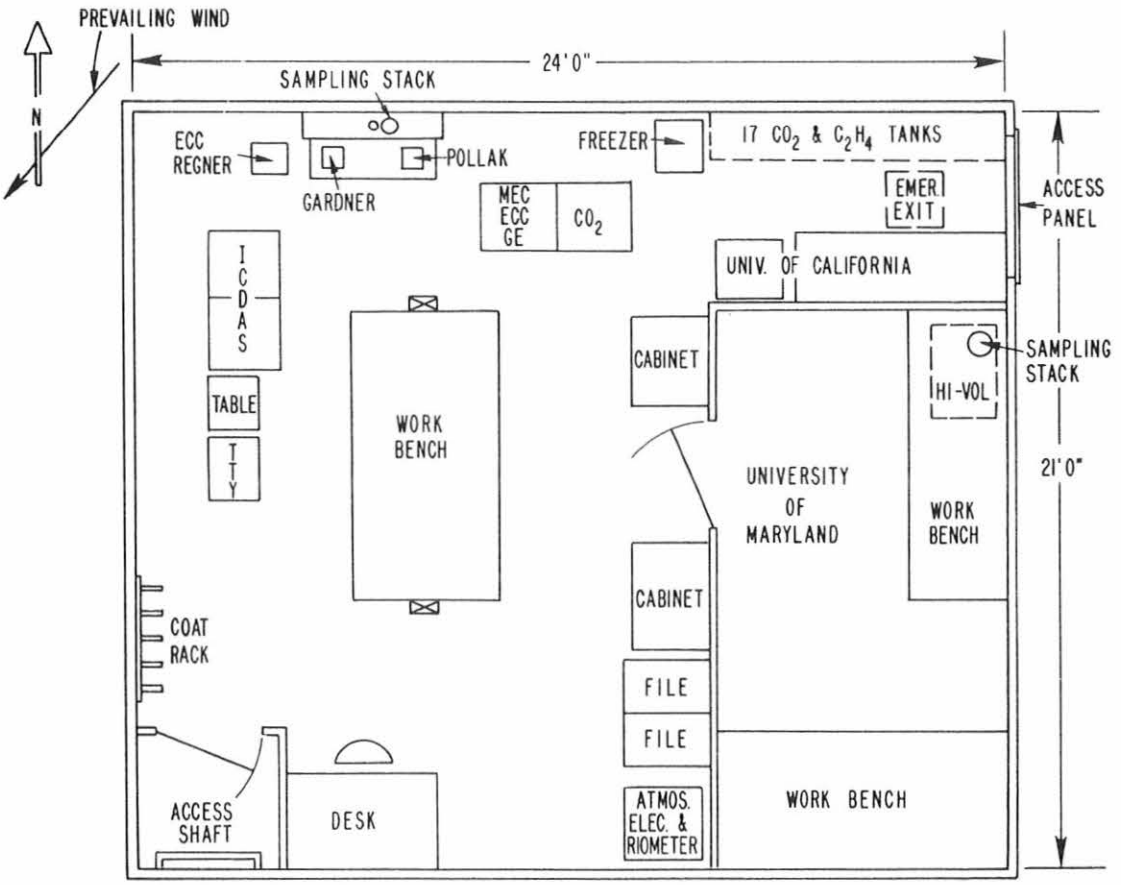


Figure 4. Clean air facility - 1975, South Pole Station, Antarctica.

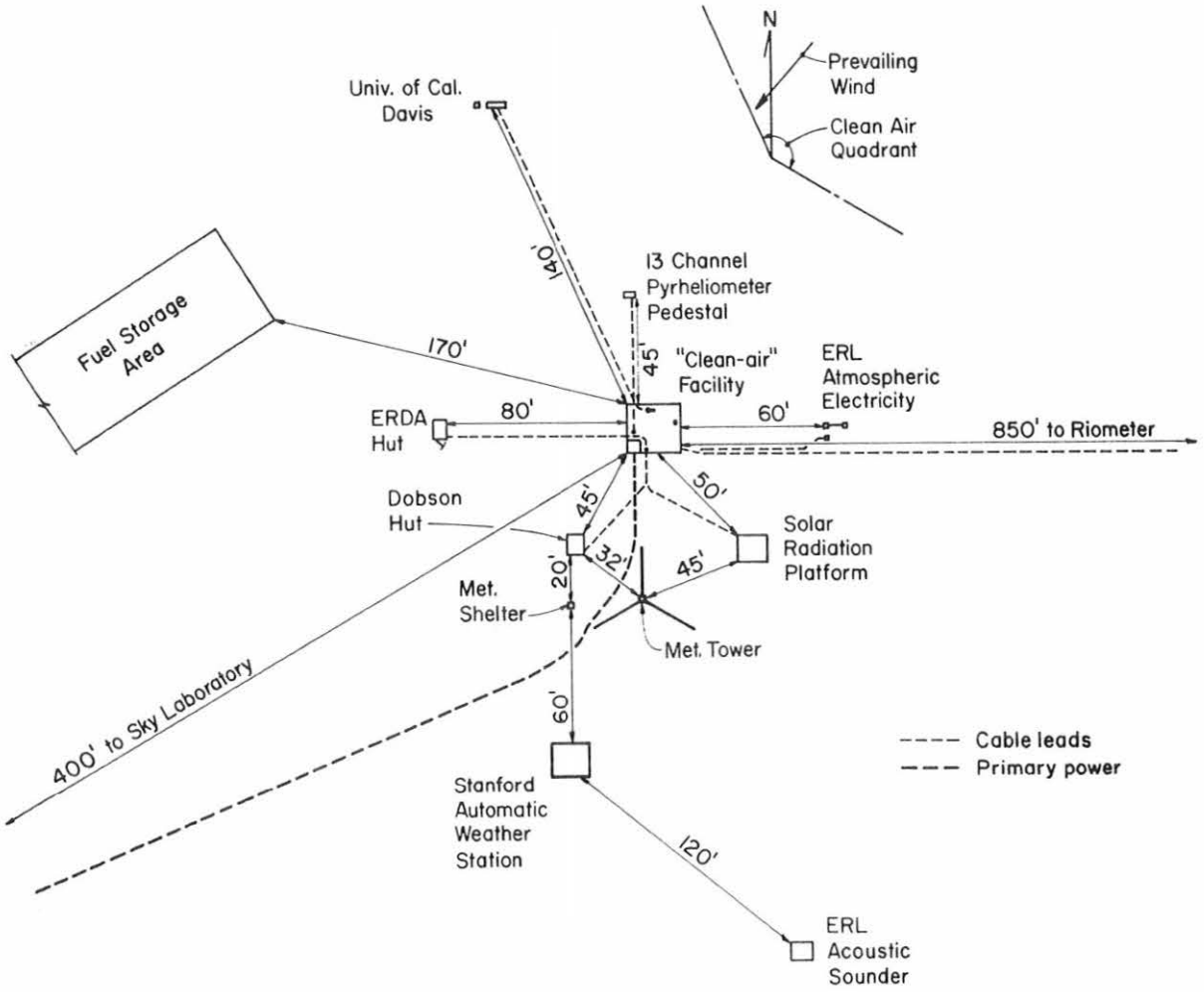


Figure 5. Surface diagram of science quadrant at South Pole Station.

A 100-kW diesel emergency generator (Fig. 8) became operational in November to supplement commercial power in times of power outage or fluctuation. The ICDAS system is equipped with an uninterruptible power supply to minimize data loss when the generator is switched on or off.

Cape Matatula was the site of a U.S. Marine radar station in World War II. Many of the original foundations had to be demolished, and Lauagae Ridge was landscaped in September to provide about 3000 m^2 of useful land adjacent to the Observatory building. In December a 183-m fence was added at the SE precipice of the Ridge for personnel protection.

A wooden stairway (Fig. 9) was completed in November between Lauagae Ridge and Matatula Point, a vertical drop of about 50 m.

Figure 6. Ribbon cutting at Samoa Observatory dedication. L. to R. Chief Iuli Togi, Tula Village; Mr. Joseph O. Fletcher, Deputy Director, ERL; Honorable Te'o, Speaker of the Samoan House.

Figure 7. Samoa GMCC Observatory building.

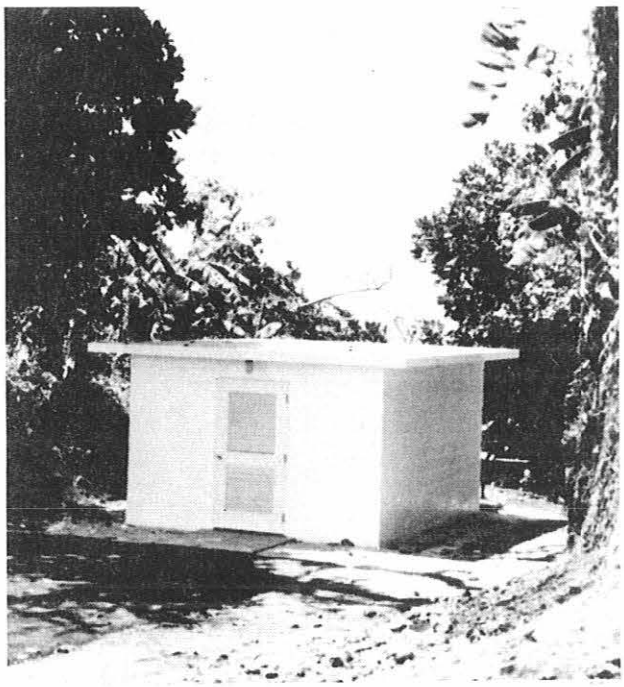


Figure 8. Samoa emergency generator facility

Figure 9. Access stairway from Lauagae Ridge to Matatula Point.

In December a 9-m air sampling tower was erected as part of a cooperative program by the University of Rhode Island under the direction of Dr. Robert Duce and funded by the National Science Foundation. An underground power line was installed to provide power for this program on the Point.

Solar radiation sensors, a URAS CO_2 analyzer, a Dobson ozone spectrophotometer, and two surface ozone monitors were installed also in December. The radiation sensors and Dobson Ash Dome are located on the upper observation deck. The ECC and Dasibi ozone meters sample air through Teflon tubing fastened to a short mast erected on the observation deck. The URAS CO_2 analyzer samples air through a 335-m polyethylene tube secured to the U.R.I. tower on Matatula Point. Meteorology sensors were also installed on the tower, with signal cables connected to ICDAS inside the building.

Plans for 1976 include erection of a remote sampling shelter near the top of the access stairway on Lauagae Ridge and a 20-m sampling tower. This installation will be used for aerosol and other selected gas monitoring programs.

2.5 Boulder

Space has been obtained at NOAA's Fritz Peak Observatory, in Colorado for the purpose of conducting selected measurement programs (particularly surface ozone observations), as well as for testing instruments at a relatively clean-air site. The observatory is operated by the ERL Aeronomy Laboratory. It is located south of Nederland, Colorado about 25 miles west of Boulder.

Elevation of the observatory site is 8,000 feet above mean sea level, while Fritz Peak itself rises to an altitude of 9,020 feet. Colorado Highway 119 runs past the observatory and although relatively heavy traffic prevails during weekends, particuarly in the summertime, a predominance of clean air is available at the site during much of the year. Prevailing winds are from the west, from the direction of the Rocky Mountain Great Divide.

3. OBSERVATORY PROGRAMS

This section summarizes the measurement programs and documents any changes such as relocation, new installation, on-station modification, or discontinuation of any program or system. A brief description of both problems and solutions is included.

3.1 Mauna Loa

Side-by-side operation of the GMCC URAS-2 and the Scripps Applied Physics carbon dioxide continuous analyzers continued through 1975 in order to obtain a substantial set of comparative data. The URAS-2 analyzer was modified to operate either by computer control or independently when the computer is not available for data acquistion.

The lidar program was expanded to include aerosol profiles in the upper troposphere in addition to those previously measured in the stratosphere. Also using data from the MLO lidar system, a program was initiated to determine the statistics of occurrence of cirrus clouds in the upper troposphere. These measurements include height, thickness, frequency of occurrence during various seasons, and optical thickness.

In the evening, during downslope wind conditions, flask samples were taken for fluorocarbon measurement. Previously, samples were taken during the daytime generally at the time of upslope winds.

In September Eppley bulb pyranometers NWS 1825 and NWS 1833, used for global radiation measurement over the past 9 years and 5 years respectively, were disconnected and returned to the National Weather Service Engineering Division for terminal calibrations. Pyranometer NWS 1825 was intercompared for one month with the GMCC Eppley Model II (12616 F3) pyranometer before being returned.

A new executive program, Basic Operating Software System (BOSS) 75170, was installed in the GMCC data acquisition system (ICDAS). It acquires and records signals from the different sensors at the observatory and controls the calibration cycles on some sensors. The installation was completed and tested during the summer and the previously used Hewlett-Packard data acquisition system was terminated in October. Backup solar radiation data were also recorded on a 24-channel Leeds & Northrup recorder and a Honeywell-Brown recorder.

Mauna Loa acted as a central calibration and operational testing facility for a number of new aerosol instruments designed for use at the other baseline stations. A modified General Electric Condensation Nucleus Counter and a four-wavelength nephelometer were tested and operated during the year and will be transferred to the Barrow Observatory in 1976. In addition, three long-tube Gardner counters and three Pollak counters were tested and compared with the MLO Pollak counter.

New sensors for atmospheric pressure, temperature, and relative humidity were installed to provide an electrical output with a linear calibration factor. In addition, a set of linear translators was provided to produce a uniform voltage for wind direction and speed. This installation was completed in November.

There were three short-term cooperative programs at Mauna Loa in 1975. During September, Dr. Jost Heintzenberg of the Institute of Meteorology, Johannes Gutenberg University, Mainz, Germany, visited the Observatory to demonstrate his new inversion technique which determines the *in situ* size distribution of the high tropospheric background aerosol.

In July a cooperative effort with Dr. Keith Bigg, CSIRO, Australia, was conducted to determine some of the chemical properties of Mauna Loa aerosols.

Dr. C. Murray Penney of the General Electric Corporate Research and Development Laboratories, Schenectady, N.Y., made an attempt in late 1975 to measure the profile of atmospheric ozone using an ultraviolet lidar system.

Mauna Loa programs operated during 1975 are listed in Table 1.

3.2 Barrow

The instrumentation control and data acquisition system (ICDAS) was installed at the station in April. Operation began with BOSS 75070 and was upgraded to BOSS 75170 during the summer. The system ran well during most of the year; however, a two-day power outage in November caused a computer failure that was not solved for over two months. New meteorological sensors were installed to measure relative humidity, air and ground temperature, barometric pressure, and wind speed and direction. All of these parameters are now fed directly into the ICDAS.

During the summer the Smithsonian Radiation Biology Laboratory (SRBL) cooperative program added a scanning UV radiometer to its array of pyranometers on the roof platform.

Two new cooperative measurement systems were added to the station's programs. These are: 1) a prototype spectrometer to measure stratospheric NO_2 for NOAA's Aeronomy Laboratory, Boulder, Colorado; and 2) a high-volume air sampler for surface aerosol measurements for the ERDA Health and Safety Laboratory, New York. The latter system was installed on the new ERDA platform together with three other high-volume samplers operated for the Desert Research Institute.

New ECC and Dasibi surface ozone instruments were installed in July and a Pollak condensation nucleus counter and a new CO_2 UNOR analyzer were also put on-line during the summer. Table 2 lists those programs in operation at Barrow.

Table 1. 1975 Summary of Sampling Programs at Mauna Loa

Monitoring Programs	Instrument	Sampling Frequency	Data Record
Gases			
Carbon dioxide	Evacuated Glass Flask (SIO)	2/month	Oct 1958 - present
	Applied Physics infrared gas analyzer (SIO)	Continuous	Oct 1958 - present
	URAS-2 infrared gas analyzer	Continuous	June 1974 - present
Surface ozone	Electrochemical concentration cell (ECC)	Continuous	Sept 1973 - present
Total ozone	Dasibi ozone meter	Continuous	July 1975 - present
	Dobson spectrophotometer	Discrete	Oct 1957 - present
Fluorocarbons	Evacuated flask	1/week	Sept 1973 - present
Aerosols			
Atmospheric particulates (height distribution)	Lidar	1/week	Apr 1973 - present
Condensation nuclei	Gardner counter	Discrete	Sept 1967 - present
	General Electric counter	Continuous	Sept 1973 - present
	Pollak counter	Discrete	July 1973 - present
Optical properties	Four-wavelength nephelometer	Continuous	Jan 1974 - present
Solar Radiation			
Global spectral irradiance	Ultraviolet radiometer	Continuous	Apr 1972 - present
	Four Eppley pyranometers	Continuous	May 1972 - present
	Eppley bulb-type pyranometer	Continuous	Jan 1958 - Sept 1975
Direct spectral irradiance	Eppley normal incidence pyrheliometer	Continuous	Jan 1958 - present
Water vapor	Foskett	Continuous	July 1967 - present
Solar aureole	Aureole camera	1/week	June 1974 - present
Meteorology			
Temperature/dewpoint	Hydrothermograph	Continuous	1955 - present
Pressure	Barograph	Continuous	1955 - present
Precipitation	8" raingage	Daily	Dec 1956 - present
	Tipping bucket gage	Continuous	Dec 1956 - present
Precipitation chemistry-GMCC	pH meter, bridge, electrodes	Discrete	Oct 1974 - present
Winds	Anemometer	Continuous	Dec 1956 - present
Cirrus clouds	Lidar	1/week	Apr 1973 - present
Cooperative Programs			
Carbon monoxide-Max Planck Inst.	Chemical reaction with HgO	Continuous	Aug 1973 - present
SO_2, NO_x, NH_3, H_2S NCAR	Chemical bubbler system	1/2 weeks	- July 1975
SO_2, NO_2 - EPA	Chemical bubbler system	1/2 weeks	Aug 1971 - present
Total surface particulates - ERDA	Hi-volume filter	Intermittent	1970's - present
Turbidity - EPA	Dual wavelength sunphotometer	Discrete	1960's - present
Precipitation chemistry-EPA	Misco collector	Discrete	Mar 1973 - present
Rain Sr^{90} - ERDA	Ion exchange column	1/month	Nov 1955 - present
Aerosol particles for analysis - CSIRO	Impactor/precipitator	Discrete	Aug 1971 - present
Surface Tritium - U. of Miami	Molecular sieve	2-day averages	Aug 1971 - present
Solar Radiation Erythema Spectrum-Temple Univ.	Ultraviolet meter	Continuous	Dec 1973 - present

Table 2. 1975 Summary of Sampling Programs at Barrow

Monitoring Programs	Instrument	Sampling Frequency	Data Record
Gases			
Carbon dioxide	UNOR infrared gas analyzer	Continuous	Mar 1973 - present
	Evacuated glass flask	1/week	Apr 1971 - present
Total ozone	Dobson spectrophotometer	Discrete	Aug 1973 - present
Surface ozone	Electrochemical concentration cell (ECC)	Continuous	Mar 1973 - present
	Dasibi ozone meter	Continuous	July 1975 - present
Fluorocarbons	Evacuated flask	1/week	Sept 1973 - present
Aerosols			
Condensation nuclei	Gardner counter	Discrete	Sept 1971 - present
	G.E. condensation nucleus counter	Continuous	May 1973 - Nov 1974
	Pollak counter	Discrete	Oct 1975 - present
Solar Radiation			
Global spectral irradiance	Four Eppley pyranometers	Continuous	June 1974 - present
	Ultraviolet radiometer	Continuous	June 1974 - present
Meteorology			
Temperature	Hygrothermograph	Continuous	Feb 1973 - present
Dewpoint temperature	Hygrothermograph	Continuous	Feb 1973 - present
Pressure	Microbarograph	Continuous	Feb 1973 - present
Precipitation	8" raingage	Discrete	Feb 1973 - present
Snow cover	Observer	Discrete	Oct 1974 - present
Wind speed/direction	Bendix aerovane	Continuous	Feb 1973 - present
Air & ground temperatures	Remote sensors (thermistors)	Continuous	Nov 1975 - present
Relative humidity	Remote sensor	Continuous	Nov 1975 - present
Pressure	Transducer	Continuous	Nov 1975 - present
Cooperative Programs			
Turbidity - ERDA	Dual wavelength sunphotometer	Discrete	Mar 1973 - present
Precipitation chemistry - EPA	Misco collector	Discrete	Sept 1973 - Sept 1975
Sfc. global radiation - SRBL	Eppley pyranometers	Continuous	Apr 1973 - present
	Scanning UV radiometer	Continuous	May 1975 - present
Total surface particulates - DRI	Hi-volume sampler	Continuous	Oct 1973 - present
CO_2 sampling-Scripps	Evacuated flask	2/month	Jan 1974 - present
Total surface particulates - ERDA	Hi-volume sampler	Continuous	Aug 1975 - present
Total NO_2 -Aeronomy Lab, NOAA	NO_2 spectrometer	Discrete	Aug 1975 - present

3.3 South Pole

Table 3 lists GMCC and cooperative programs that were in operation at South Pole Station ("Pole") during 1975. Following is a brief review of equipment performance and some of the operational difficulties.

Table 3. 1975 Summary of Sampling Programs at South Pole Station

Monitoring Programs	Instrument	Sampling Frequency	Data Record
Gases			
Carbon dioxide	URAS infrared gas analyzer	Continuous	Jan 1975 - present
	Evacuated glass flask	2/month	Jan 1975 - present
Surface ozone	Electrochemical concentration cell (ECC)	Continuous	Dec 1971 - present
	Chemiluminescent meter (MEC)	Continuous	Jan 1974 - present
Total ozone	Dobson spectrophotometer	Discrete	Dec 1963 - present
Aerosols			
Condensation nuclei	General Electric counter	Continuous	Jan 1974 - present
	Pollak counter	Discrete	Jan 1974 - present
Solar Radiation			
Global spectral irradiance	Four Eppley pyranometers	Continuous during daylight period	Feb 1974 - present
	Ultraviolet radiometer	Continuous during daylight period	Feb 1974 - present
	Normal incidence pyrheliometer	Continuous during daylight period	Oct 1975 - present
Meteorology			
Temperature	Thermistor	Summer only	Dec 1975 - present
Pressure	Transducer	Continuous	Dec 1975 - present
Wind speed/direction	Bendix aerovane	Continuous	Dec 1975 - present
Cooperative Programs			
CO_2 sampling - Scripps	Evacuated glass flask	1/week	1955 - present
Total surface particulates - ERDA	Hi-volume filter	Intermittent	May 1970 - present
Turbidity - ERDA	Dual wavelength sunphotometer	Discrete	Jan 1974 - present
C_{14} sampling	Pressurized steel flask	1/week	Jan 1974 - present

3.3.1 Carbon Dioxide

Continuous CO_2 monitoring at Pole commenced in mid-January 1975 at the "clean air" facility with a URAS-2T continuous analyzer (serial number 029), and proceeded substantially uninterrupted to the end of the year. The analyzer obtained samples of outside air through aluminum tubing approximately 10 meters long that extended to the top of the sampling manifold stack, and the output was recorded with a Hewlett-Packard 7127A Strip Chart Recorder. The analyzer exhibited a persistent monotonic downscale drift throughout most of the year. Despite thorough investigation of the electronic, mechanical, and optical components of the URAS-2T, the reason for this drift was not discovered.

A flask CO_2-sampling apparatus was added to the South Pole CO_2 analyzer system in mid-January 1975. This apparatus allows simultaneous filling of pairs of flasks by the air-input plumbing of the URAS-2T CO_2 analyzer. During 1975, flasks samples were collected on or about the first and fifteenth day of each month. These sampling dates and times were chosen to coincide as nearly as possible with the sampling dates and times that had been established

by the Scripps Institution of Oceanography for its flask sampling program (a cooperative program for which GMCC has responsibility for making measurements).

3.3.2 Surface Ozone

Surface ozone monitoring by the McMillan (MEC)-1100 chemiluminescent ozone analyzer (serial number 362) at old Pole was interrupted in mid-November 1974 when the rotor shaft bearings of that instruments's air pump seized. Monitoring was not resumed until mid-January 1975 after repairs to the pump and after the transfer of the GMCC program to new Pole. The operation of the MEC-1100 was twice more interrupted by failures of the air pump. After its third failure, the pump was replaced and no further problems were experienced.

Surface ozone monitoring at new Pole was also conducted with an ECC-005 electrochemical concentration cell ozone meter (serial number 2) that arrived from Boulder in mid-January. Despite the recurrent malfunction and eventual failure (in early November 1975) of an electrically-operated valve that selected ambient or filtered air inputs to the electrochemical concentration cell, the ECC-005 performed satisfactorily from mid-January 1975 until the end of the year.

Surface ozone monitoring with the ECC-002 (serial number 503) continued from mid-January until mid-November 1975. The most vexing problem with the ECC-002 was its noisy output, which became noisier as the year progressed. The noise was not caused by contaminated sensing solution, by mechanical vibration, by the sensor's electronics, or by contamination of the sensor itself. The exact source of the noise was not discovered.

The Regener ozone generator (serial number 28) that had been used at old Pole and an MEC-1000 ozone generator (serial number 314) were available at new Pole to provide sources of ozone with which to calibrate the surface ozone sensors. The MEC-1100 and the ECC-005 instruments obtained outside air at new Pole through the sampling manifold. The ECC-002 obtained outside air at new Pole through a 5-meter length of Teflon tubing which was fastened to the sampling manifold stack but which extended only 2 meters above the snow surface. During 1975, the outputs of all surface ozone sensors were recorded with Rustrak strip chart recorders.

3.3.3 Total Ozone

The Dobson total ozone spectrophotometer at Pole (serial number 80) performed adequately from turnover until mid-November 1975. The only persistent problem was that the results of the instrument's monthly mercury lamp tests often perched close to 0.40, the point at which revisions to the instrument's "Table of Settings of Q" are required.

3.3.4 Condensation Nuclei

The continuous General Electric Condensation Nucleus Counter (serial number 7007) was extensively modified in February 1975 according to an electronic design developed by the University of Washington under contract to GMCC. The modification significantly improved the instrument's threshold of detection and stability. Continuous monitoring proceeded nearly uninterrupted from late March 1975 to the end of the year despite continued deterioration of an optical coupler which had been utilized in the electronic redesign and despite some zero drift problems. The GE counter obtained samples of outside air through the sampling manifold. A Pollak nucleus counter (serial number 15) was operated at new Pole from mid-January through December. During this period, gaps in the series of measurements were occasioned only by preventive maintenance and by repairs to the instrument and its associated plumbing. Two series of Pollak measurements were made per day. The first coincided with the daily NOAA/NWS balloon launch, and the second started not less than six hours later. Each series consisted of five separate samples of outside air, the first, second, and fifth of which passed only through the sampling manifold. The third and fourth samples of each series passed through a "diffuser-denuder" after having passed through the manifold.

In mid-January, a long-tube Gardner condensation nucleus counter was received from Mauna Loa Observatory. Although the long-tube improved the detection limits, the Gardner counter still lacked the sensitivity needed for austral winter monitoring at Pole when condensation nucleus concentration would frequently fall below 30 n/cc. This was evident by the negative meter deflections that were consistently obtained.

3.3.5. Solar Radiation

At new Pole, the radiometers listed in Table 4 were all mounted atop a wooden platform located approximately 15 meters grid southeast of the "clean air" facility. A multichannel radiometer which arrived at Pole from Boulder in mid-January (a thirteen-channel pyrheliometer, serial number 4757, manufactured by The Eppley Laboratory, Inc.) was mounted on a pedestal approximately 15 meters grid north of the "clean air" facility.

Soon after the outdoor installation of the multichannel radiometer in late January, a fluid condensed on the inside face of its viewing window. The radiometer was cleaned and purged with dry nitrogen but the condensate reappeared shortly after. It was discovered that the fluid was an oil-based substance in the viewing window's gasket. The gasket was replaced with an RTV seal. A few days later, the hub of a gear in the drive train of the radiometer's solar tracker fractured. Unfortunately, this failure occurred when it was too late to obtain a replacement gear from the United States and when the machine tools necessary to repair the fractured gear had already been removed from old Pole but not installed at new Pole.

In mid-March 1975 all GMCC radiometers were removed from their outdoor mounts and stored in the building. In mid-October all GMCC radiometers were reinstalled outdoors. The multichannel radiometer's repaired solar tracker

Table 4. Radiometers Used By The GMCC Program at Pole

Radiometer Type	Serial No.	Filter	Spectral Passband nm
Precision Spectral Pyranometer, Model 2	12268F3	GG22	390-2600
"	12269F3	OG1	530-2600
"	12270F3	RG8	690-2600
"	12271F3	QG	290-4000
Ultraviolet Radiometer (pyranometer)	12349	UG11	290-380
Normal Incidence Pyrheliometer	2968	Quartz	290-4000

performed satisfactorily but oil-based crystals again formed on the inside face of the radiometer's viewing window. By the end of 1975, the multichannel radiometer had still not functioned adequately at Pole. However, all other radiometers were operational by mid-October and performed without mishap until mid-November when the Leeds & Northrup multipoint recorder used to record the outputs of the radiometers failed.

3.3.6 Instrument Control and Data Acquisition System (ICDAS)

The ICDAS served solely as an instrument control system from mid-August until mid-November 1975 and was not again completely operational until mid-November when GMCC replacement personnel arrived on station. These gaps in the operation of the ICDAS were due to hardware difficulties, software difficulties, and a lack of "hands-on" experience by the GMCC staff.

The sensor-ICDAS interface circuitry of the 1975 GMCC program was very different from the circuitry of the 1974 program. The addition of the multichannel radiometer to the solar radiation project required additional preamplifiers which could not be accommodated by the 1974 circuitry without considerable modification, and in 1975 only the signals of the radiometers required amplification before processing whereas in 1974 all sensor outputs required amplification. Several problems with the tape drive and the teletype remained unsolved in 1975. The ICDAS at Amundsen-Scott was modified in December 1975 so that the hardware conformed to that at all other observatories. The modification included replacing the original display clock and adding a new multiplexer access to the system. The size of the core memory in the minicomputer was also increased from 8k to 16k bytes. Thus, the latest version of the executive program, BOSS-75345, could be accommodated. Sensors to measure atmospheric pressure and temperature (summer only, 0 to -55°C) were added and translators for the wind measurements were installed in December.

3.4 Samoa

Gas sampling and meteorological measurements begun in 1973 continued through 1975. The lack of commercial power during this period necessitated the use of portable battery or spring powered instruments. Wind speed and direction, air temperature, and rainfall were measured on Point Matatula. Relative humidity, air temperature, and barometric pressure were measured on Lauagae Ridge. CO_2 and fluorocarbon flask samples and condensation nucleus measurements were taken in both locations. EPA rain samples and ERDA turbidity measurements were taken at the NWS weather station at the airport in Tafuna.

The observatory building was completed in September, and instrument installation continued through the last quarter of 1975. Solar radiation sensors and the Dobson spectrophotometer dome were installed on the upper observation deck. The URAS CO_2 sampling line and several meteorological sensors were attached to the University of Rhode Island sampling tower on Point Matatula. The ECC and Dasibi ozone instruments were installed in the main building and included a short sampling mast erected on the upper observation deck. The ICDAS was installed in January, 1976.

Table 5 summarizes the Samoa sampling programs.

Table 5. 1975 Summary of Sampling Programs at Samoa

Monitoring Programs	Instrument	Sampling Frequency	Data Record
Gases			
Carbon Dioxide	Evacuated glass flask	1/week	July 1973 - present
Fluorocarbons	Evacuated stainless steel flask	1/week	Sept 1973 - present
Aerosols			
Condensation nuclei	Gardner counter	Discrete	June 1973 - present
Meteorology			
Air temperature	Hygrothermograph	Continuous	June 1973 - present
Dewpoint temperature	Sling psychrometer	Discrete	June 1973 - present
Air pressure	Microbarograph	Continuous	Feb 1974 - present
Precipitation	Rainfall collector	Continuous	June 1973 - present
Wind speed/direction	MRI automated weather station	Continuous	June 1973 - present
Cooperative Programs			
Precipitation chemistry -EPA	MISCO collector	Continuous	Aug 1973 - present
Turbidity -ERDA/WMO	Eppley dual wavelength sunphotometer	Discrete	Aug 1973 - present
SO_2, NO_x, NH_3, H_2S	NCAR	Chemical bubbler system	2/month	Oct 1973 - Dec 1974

3.5 Boulder

Observing programs conducted in Boulder by the GMCC Laboratory staff not only serve to gather selected data, but are useful also for purposes of training observers and testing instrumentation.

3.5.1 Total Ozone

Measurements are made on the roof of RB #3 with Dobson spectrophotometer No. 82. This is a continuing program that was initiated in Boulder in 1966. Observational data are routinely processed and results are sent to the Meteorological Service, Canadian Department of Transport, for publication in "Ozone Data for the World".

3.5.2 Erythemal Irradiance

This program was initiated in Boulder in May 1975, after similar observations, under sponsorship of the CIAP Program, U.S. Department of Transportation, were terminated at Bismarck, North Dakota, and Tallahassee, Florida. Results of the Bismarck and Tallahassee measurements have been summarized in a report submitted to the Department of Transportation (Machta et al., 1975). The purpose of the Boulder measurements is to continue investigations, at a moderately high altitude station, of the relations governing near ground level variations in solar ultraviolet radiation that causes sunburn and skin cancer with changes in atmospheric total ozone amount. An additional measurement goal is to compare observed erythemal ultraviolet (UV) irradiance values with results deduced theoretically for the Boulder location.

3.5.3 Solar Radiation

Partially in support of the erythemal irradiance measurements program, observations were conducted in Boulder during September 4 to October 30, 1975, with a quartz global pyranometer (Serial No. 12276) and with a broadband UV radiometer (Serial No. 12350).

3.5.4 Atmospheric Turbidity

Measurements of atmospheric turbidity with an EPA dual wavelength sun photometer began in Boulder in August 1975, and are continuing on a routine operational basis.

3.5.5 Surface Ozone

A program to measure surface ozone was initiated at Fritz Peak Observatory in the mountains near Boulder in April 1975. Data obtained at this relatively clean-air mid-latitude continental location will be compared with

data gathered at the GMCC stations. The ozone data are, furthermore, used by the NOAA/ERL Aeronomy Laboratory staff in their interpretation of NO_2 measurements made at the Observatory.

The measurements were made with an ECC (Electrochemical Concentration Cell) ozone meter. Comparison observations were obtained during most of the time with a photometric Dasibi ozone meter.

4. GMCC MEASUREMENT PROGRAMS

This section provides both qualitative and quantitative information on individual measurement systems, and presents representative data collected and analyzed during the year.

4.1 Measurement of Gases

4.1.1 Carbon Dioxide

Comparison of GMCC's URAS-2 continuous analyzer (Serial No. 37626682) and Scripps Institution's Applied Physics Analyzer continued at Mauna Loa during 1975. Collection of data with both instruments, which began in June of 1974, will continue until the data have been satisfactorily correlated. A lightning strike in December disabled the URAS-2 analyzer for one month, but the Applied Physics Analyzer was not affected.

A URAS-2T instrument (Serial No. U2T0029) was operated at Amundsen-Scott station in the Antarctic for the entire year. Loss of reference gases and a downward zero drift in the analyzer troubled the program but good quality data were recorded throughout most of the year. The data will be reduced during the first half of 1976.

In December 1975, a fourth GMCC continuous CO_2-analyzer was put into operation at the Samoa Observatory. It, too, is a URAS 2T (Serial No. U2T0029).

The UNOR-2 CO_2 analyzer in operation at Barrow since March 1973 developed serious electronic problems and was replaced with another UNOR-2 (Serial No. 63168) in August. As a result of this deterioration in instrument performance, the July data are of poorer quality.

Table 6 lists the provisonal monthly mean CO_2 concentrations determined from analyzer measurements at Barrow and Mauna Loa for 1975. All values are expressed in CO_2 ppm based on the Scripps Institution of Oceanography Index Scale.

A new method of flask sampling was initiated at several of the GMCC stations during 1975. Whereas previously quasi-simultaneous CO_2 flask pair samples were collected manually by an observer, the new technique employs a flask sampling apparatus built into the rack of the continuous CO_2 analyzer in use at the station. By activation of a solenoid valve, air that normally passes from the air intake line into the analyzer is diverted into the pair of glass flasks for simultaneous flushing and filling to an overpressure of 1 or 2 psi. An advantage of the new sampling method is that the collection of identical air samples is assured. Should analyses yield different values for a sample pair, then the difference must arise from collection vessel contamination or from the analysis technique. An additional important feature of the new sample collection method is that it allows intercomparison of the

Table 6. Provisional Monthly Mean CO_2 Concentrations

1975	Barrow, Alaska	MLO, Hawaii
Jan.	330.23 ppm	324.24 ppm
Feb.	331.99	325.32
Mar.	330.37	325.23
Apr.	330.22	326.05
May	331.28	326.56
Jun.	328.21	326.00
Jul.	323.62	325.33
Aug.	319.54	323.24
Sept.	320.35	322.06
Oct.	323.95	322.34
Nov.	327.41	323.06
Dec.	328.98	Missing

calibration levels of all field station CO_2 analyzers since analysis of all samples is performed by means of a reference analyzer maintained at the GMCC Techniques and Standards Laboratory in Boulder.

The sampling method described above was initiated at South Pole station in January 1975. Sampling throughout the year was performed at a frequency of twice per month. A small fracture in a short length of air intake line inside the observatory building caused room air to leak into the analyzer during April to June, resulting in the collection of contaminated samples.

CO_2 flask sampling was continued at Barrow during all of 1975, with the new sampling technique described above initiated in June. The sampling frequency was once per week.

Hand-aspirated, weekly, CO_2 flask samples were also collected at the Samoa Observatory until December 1975, at which time a change was made to the new flask sampling method.

Provisional 1975 mean monthly CO_2 concentrations for the three stations mentioned above are given in Table 7. These flask sampling data are shown graphically in Figure 10.

Through-the-analyzer CO_2 flask sampling is planned for Mauna Loa, beginning early in 1976. We expect, furthermore, to resume soon the collection of hand-aspirated CO_2 flask samples at Niwot Ridge, Colorado, and Key Biscayne, Florida. In addition, a new manual sampling program will be commenced at Cape Kumukaki, Hawaii.

Table 7. Provisional Mean Monthly CO_2 Index Values Determined From Flask Sampling in 1975

Month	South Pole			Samoa			Barrow		
	# of Samples	Mean Conc. Index	σ	# of Samples	Mean Conc. Index	σ	# of Samples	Mean Conc. Index	σ
Jan.	1	323.77	-----	4	324.31	1.13	4	331.51	2.87
Feb.	2	323.53	0.11	+	Msg		4	330.26	0.96
Mar.	2	323.71	0.39	3	325.31	0.94	4	329.84	0.42
Apr.	2	(324.16)	0.46	2	323.69	0.13	2	328.95	2.41
May	2	(326.38)	1.82	4	325.36	1.49	5	330.17	0.24
June	2	(328.07)	2.23	2	326.45	2.96	*5	328.56	4.04
July	2	323.91	0.04	3	325.42	0.70	2	323.31	2.08
Aug.	2	324.64	0.03	4	327.20	4.45	6	319.51	1.97
Sept.	2	325.03	0.55	2	325.12	0.86	5	320.78	1.56
Oct.	2	324.67	0.25	2	325.68		6	323.41	0.63
Nov.	2	324.64		++	Msg		6	327.31	2.57
Dec.	2	325.10		1	324.87	-----	4	332.57	4.23

Data in parentheses affected by air intake line leak.
+Station closed - Mr. Rumble was in Boulder for the annual meeting.
++No samples obtained during Nov. and part of Dec. Simultaneous sampling was begun mid-Dec.
*Simultaneous flask sampling started on 10 June 1975.

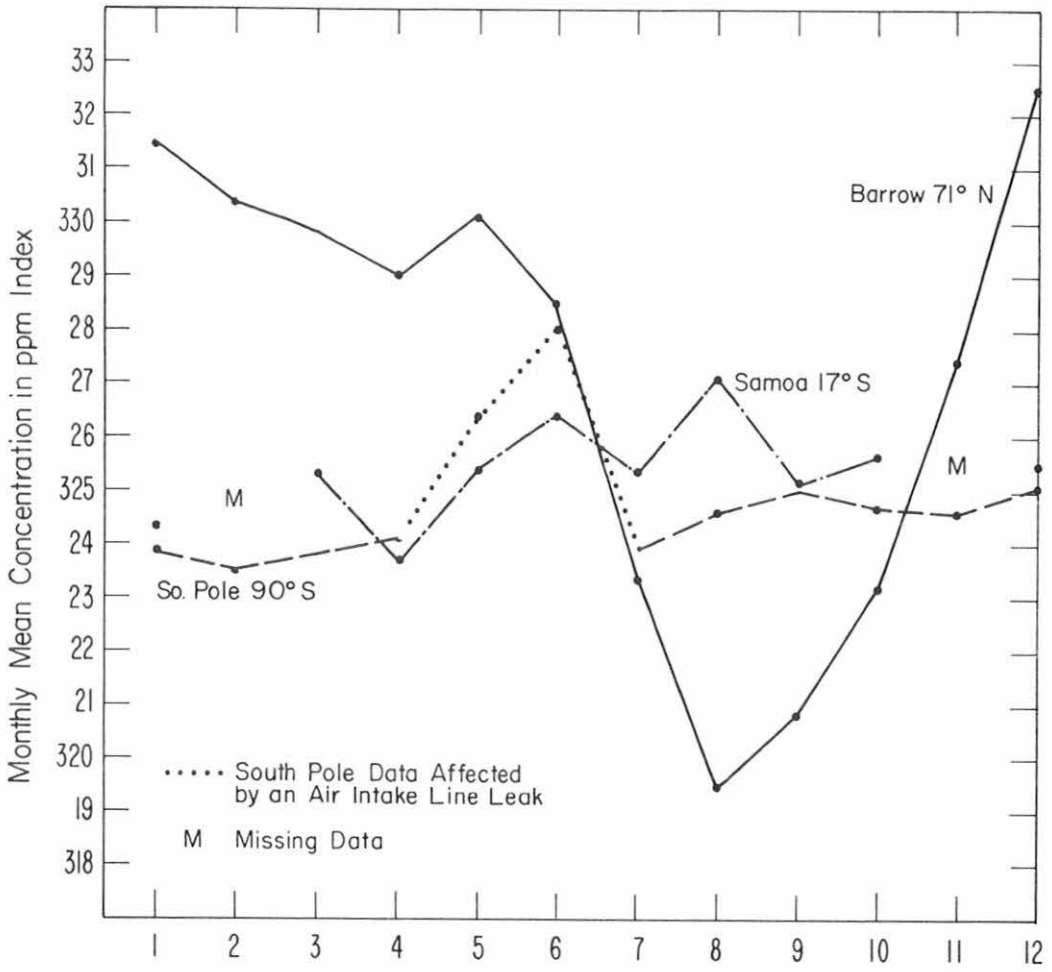


Figure 10. Flask sampling CO_2 data, 1975.

4.1.2 Total Ozone

The U.S. Dobson spectrophotometer network now comprises thirteen stations where measurements are made of total ozone on a daily basis (Table 8).

The last station to be established was that in Samoa. Routine observations began December 19, 1975, at the Samoa GMCC Observatory (Fig. 11) located on Tutuila Island, American Samoa (14°15'S, 170°34'W).

In view of the increasing importance of atmospheric ozone research and in consideration of the fact that no total ozone observatories are located west of the Rocky Mountains, a decision was made early in 1975 to move the Green Bay, Wisconsin, Dobson station to some western location. Relocation of an existing facility rather than establishment of a new one is necessary since the supply of ozone spectrophotometers is critically low and the instruments are no longer commercially available. Furthermore, comparisons of

Table 8. The U. S. Dobson Spectrophotometer Network

Station	Period of Record	Instr. Ser. No.	Agency
Bismarck, N.Dak.	010163-Present	33	NOAA-ARL
Caribou, Maine	010163-Present	34	NOAA-ARL
Green Bay, Wis.	102063-063075	38	NOAA-ARL
Tutuila Is., Samoa	121975-Present	42	NOAA-ARL
Tallahassee, Fla.	060273-Present	58	Fla. State U.
Mauna Loa, Hawaii	010264-Present	63	NOAA-ARL
Wallops Island, Va.	070167-Present	72	NOAA-ARL
Barrow, Alaska	080273-Present	76	NOAA-ARL
Nashville, Tenn.	010163-Present	79	NOAA-ARL
Amundsen-Scott	120563-Present	80	NOAA-ARL
Boulder, Colo.	090166-Present	82	NOAA-ARL
White Sands, N.Mex.	010572-Present	86	Dept. of Army
Huancayo, Peru	021464-Present	87	NOAA-ARL

the Green Bay and Toronto, Canada, ozone data for the past decade have indicated that data from either station are representative for the region. Final measurements of total ozone were made at Green Bay on June 30, 1975.

The new western location has not yet been chosen although several sites are under investigation, particularly in the Southwest. Since terminating the Green Bay, Wisconsin, station, we have acquired Dobson spectrophotometer No. 94 on loan from the Department of Meteorology, Naval Postgraduate School, Monterey, Calfifornia. This instrument will be used at our western station.

MODERNIZATION OF DOBSON SPECTROPHOTOMETERS

During the spring of 1975, work was completed on modifying the electronic and electromechanical systems of Dobson spectrophotometer No. 42. All Dobson ozone instruments used at stations in the U.S. network, with the exception of Huancayo, Peru, now employ miniature solid-state, built-in high-voltage converters, modern solid-state amplifier circuitry, and electromechanical phase-sensitive rectifiers. Since the modification program began in 1971, essentially no data have been lost because of inoperative instruments. Furthermore, problems experienced in the past, such as low instrument sensitivity and low signal-to noise ratio, have been virtually eliminated.

Work has also begun in replacing original Dobson spectrophotometer shutter motors and drive assemblies of English manufacture with more readily

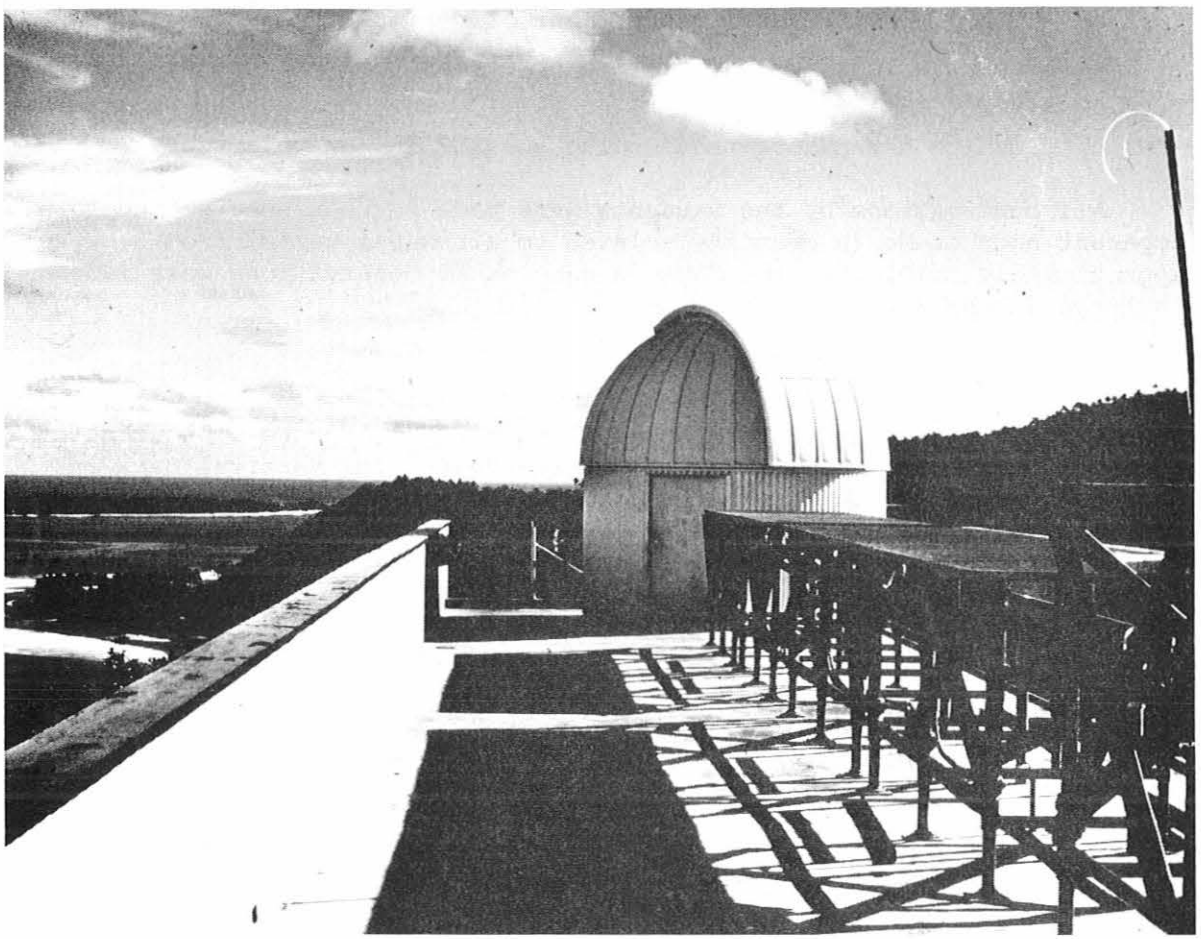


Figure 11. Samoa GMCC Observatory.

procurable components made in the U.S. The new assemblies employ nylon belt rather than friction pulley drives, and synchronous 1800-rpm motors with a torque of 0.6 inch-ounce. To date, motor and drive assemblies have been modified in the Boulder, Caribou, Nashville, Samoa, and White Sands instruments.

CALIBRATIONS

In 1972 a program was initiated to calibrate each Dobson instrument in the U.S. network every two or three years. In accordance with this plan, the Nashville, Caribou, Boulder, and Samoa spectrophotometers were recalibrated at Boulder, Colorado, during 1975.

In order to improve the quality of the total ozone data at the Nashville and Caribou stations, students were hired to take special observations during June, July, and August of 1975. These special observations were of three types:

a. Quasi-simultaneous observations of various types

b. Observations for calibrating spectrophotometers on an Absolute Scale

c. Zenith sky observations using the HNP linear polarizer

All observations by the students were made between sunrise and local apparent noon as Mu (a quantity related to air mass) varied from 3.50 to approximately 1.10. On some days as many as 60 observations were made. Analysis of the data is in progress.

DATA

Figure 12 shows plots of the mean monthly total ozone amounts determined at the stations in the U.S. network during 1975. The vertical bars in the plots are standard deviations associated with the means and represent natural variability in the data as well as observer and instrument errors. The Nashville, Caribou, and Amundsen-Scott data for 1975 have been designated "provisional" because final corrections to the data have yet to be applied.

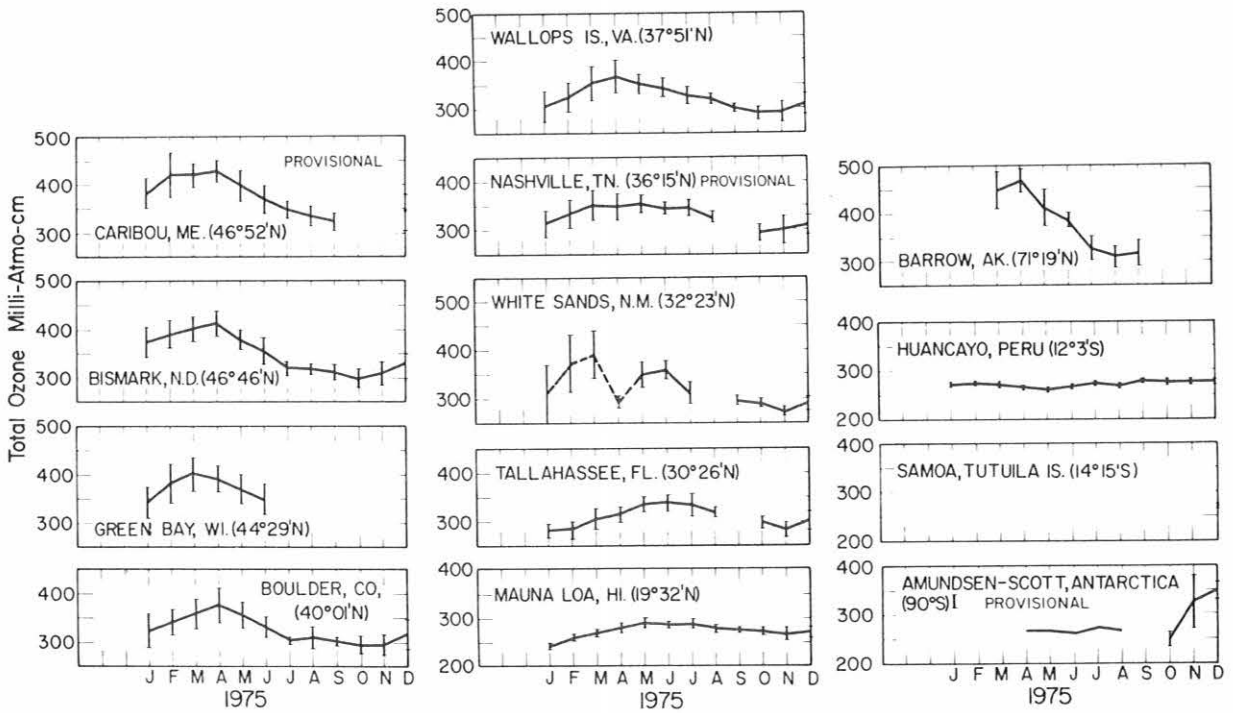


Figure 12. Mean monthly total ozone with standard deviations for the U.S. Dobson ozone spectrophotometer network, 1975.

4.1.3 Surface Ozone

This year marked completion of the deployment of updated electrochemical concentration cell (ECC) ozone meters (see Summary Report No. 1 for a description of the meters' principle of operation) to all four GMCC observatories. In addition, an ultraviolet absorption ozone photometer (Dasibi), described later in this section, was installed at each of the observatories. At the South Pole, measurements were continued using the chemiluminescent ozone analyzer.

Surface oxidant measurements were continued at Boulder and a new observing site was established at the Fritz Peak Observatory in the mountains west of Boulder. In addition to providing a nearby site for making routine measurements in air that is considerably less contaminated than that at Boulder, the Fritz Peak location is being used for instrument testing and calibration.

DATA PROCESSING AND ARCHIVING

During 1975 procedures were worked out with the Canadian Department of the Environment, the agency responsible for publishing atmospheric ozone data under an agreement with the World Meteorological Organization, for publication of surface ozone data from the GMCC network. Data published will be daily means, maxima, and minima, as well as the monthly averages of these quantities. The data indicated as archived in Table 9 have been submitted to Canada for publication in the format illustrated in Figure 13. They will be available from the Canadian agency at a nominal cost.

The larger set of data consist of hourly average surface ozone partial pressures for the four GMCC locations and for the auxilliary stations at Boulder and Fritz Peak, and data gathered prior to 1973. All data are contained on magnetic tape or punch cards and on microfilm at Boulder.

DATA SUMMARY

The use of both an ECC and a chemiluminescent or Dasibi-type ozone analyzer at the GMCC locations provides a redundancy in the measuring systems. The primary feature desired in an ozone measuring system is the ability to make measurements on an absolute scale at the generally low ozone concentrations found in clean tropospheric air at the GMCC observatories. The need for absolute measurements has become increasingly apparent in light of difficulties experienced in calibrating and maintaining a secondary ozone standard.

The ECC ozone meter was chosen for use initially because of its ability to measure ozone on an absolute scale, its availability at minimal cost, and previous experience with its operation. Concern was expressed about this instrument because of possible interferences by other gases and the somewhat slow (20-second exponential) response. Neither of these concerns was justified, however, because interfering gases appear to exist at very low concentrations at the GMCC baseline locations, and ozone changes take place on the scale of hours or even days so that the response of the meter is more than adequate. A more persistent problem in operating the ECC meter has been sensing solution integrity. Inadvertent introduction of oxidants or reductants

Table 9. Status of Processing and Archiving of Surface Ozone Data

STATION	PROCESSED	ARCHIVED
BARROW		
ECC	Mar 73 - Dec 75	Mar 73 - Dec 75
Dasibi	Jul 75 - Dec 75	------
MAUNA LOA		
ECC	Aug 73 - Dec 75	Aug 73 - Dec 75
Dasibi	Sep 75 - Dec 75	------
SAMOA		
	None	None
SOUTH POLE		
ECC	Jan 75 - Dec 75	------
MEC Chemilu	Mar 74 - Dec 75	Mar 74 - Dec 75
BOULDER		
ECC	May 73 - Dec 75	
FRITZ PEAK		
ECC	Apr 75 - Dec 75	
Dasibi	Apr 75 - Dec 75	

SURFACE OZONE MEASUREMENTS FROM SELECTED STATIONS

```
DATE   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
BARROW, ALASKA                FEBRUARY    1974
MEAN  25 28 31 27 26 31    25 22 23 24 16    14 26 25 24 29 28
MAX   27 30 32 30 30 34    26 24 27 26 18    19 30 30 31 37 31
HH    16 20 15 01 23 20    06 17 18 07 03    12 22 14 17 18 03
MIN   23 22 30 22 24 29    20 17 19 21 14     7 17 14 12 23 24
  EXTREMES: MAX  37, MIN  7. MONTHLY MEANS: MEAN 25, MAX  28, MIN 20.EQUIPMENT ECC
BARROW, ALASKA                APRIL       1974
MEAN                                                                  13  4 21 19 27
MAX                                                                   18 20 30 33 35
HH                                                                    03 23 22 23 03
MIN                                                                    6  1 15  5 19
  EXTREMES: MAX  35, MIN  1. MONTHLY MEANS: MEAN 17, MAX  27, MIN  9.EQUIPMENT ECC
BARROW, ALASKA                MAY         1974
MEAN  28 20 35 30 19 26  9  4  5  6  6 18 20 15 14 18 18 26 27 30 15 23 33 29 26 22 20 23 28 26 24
MAX   37 34 40 36 26 28 21 10  8  9 15 23 24 18 16 21 22 30 34 33 24 39 37 34 29 29 27 28 31 29 29
HH    03 23 16 01 19 08 00 06 07 20 23 10 10 02 23 20 01 08 16 15 00 16 21 18 01 00 01 20 17 22 13
MIN   20 13 32 24 13 22  1  1  1  1  1 15 15 12 12 15 16 20 19 22 11  9 27 20 21 17 14 15 25 24 20
  EXTREMES: MAX  40, MIN  1. MONTHLY MEANS: MEAN 21, MAX  26, MIN 15.EQUIPMENT ECC
BARROW, ALASKA                JUNE        1974
MEAN  18 19 14 17 16 13 14 16 22  8  7 16 23 13 14 12 16 25 24 21 27 26 17 20 28 29 29 30 26 23
MAX   20 28 17 19 20 29 33 17 25 14 14 21 34 15 16 16 21 34 28 23 29 28 22 24 33 34 34 33 28 25
HH    20 05 18 23 08 22 02 13 12 00 23 23 04 06 21 22 18 12 02 22 16 16 00 11 22 23 01 18 19 19
MIN   11  9  9 15 13  9  5 10 15  5  4 13 11 10 11  9 12 15 11 18 22 24 12 13 20 26 22 27 24 21
  EXTREMES: MAX  34, MIN  4. MONTHLY MEANS: MEAN 19, MAX  24, MIN 14.EQUIPMENT ECC
BARROW, ALASKA                JULY        1974
MEAN  22 21 25 15 15 [illegible]                                                  16 19 18 19 11 10 [illegible] 16 14
MAX   25 25 32 [illegible]                                                        22 23 25 15 [illegible] 22 22
HH    18 [illegible]                                                              [illegible]
```

Figure 13. Format of GMCC data published by the Canadian Department of the Environment.

into the sensing solution produces noisy signals and raises uncertainties in the absolute amount of ozone recorded.

The first attempt at ozone measurements with a second instrument used the chemiluminescent analyzer described in Summary Report No. 3. Such instruments are known to be relatively free of interferences, are fast responding, and do not require the use of liquids. They do, however, require the use of ethylene gas, and do not measure ozone on an absolute scale. A chemiluminescent ozone analyzer was used at South Pole in 1974 and 1975. ECC meters were also used there. However, the ECC meter operated at South Pole in 1974 was subject to gross sensing solution contamination and produced few useful data.

The chemiluminescent analyzer at South Pole, on the other hand, was subject to thermal drift and there is an uncertainty in the absolute values assigned to the data. The ozone generators used as secondary standards were not as stable as had been anticipated, and were found later to require extensive modifications.

Figure 14 shows the hourly average surface ozone amounts obtained during November and December 1975 when both the ECC and chemiluminescent analyzers appeared to be working well. Figure 15 shows the mean monthly values for 1975 as recorded by the two analyzers. There is a significant difference in

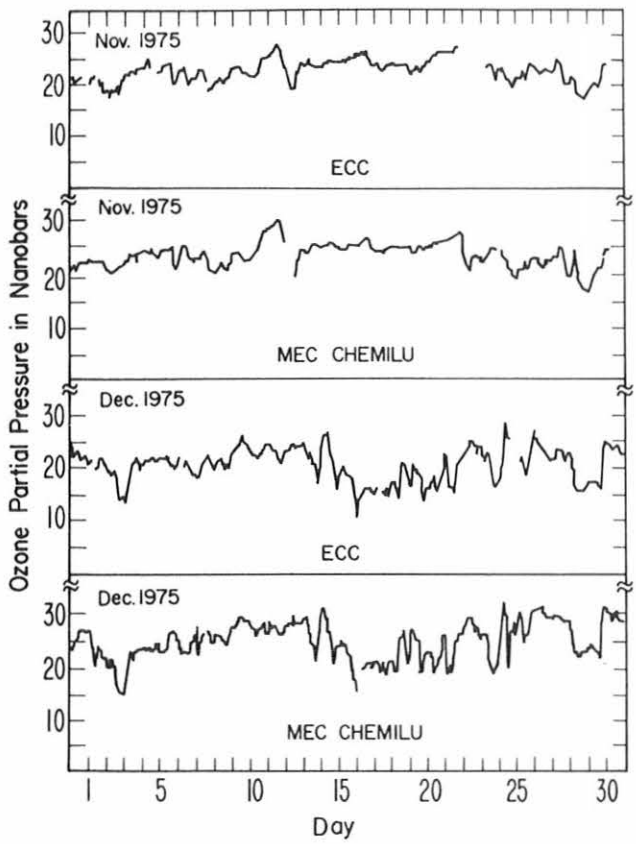


Figure 14. Hourly surface ozone at South Pole for two months.

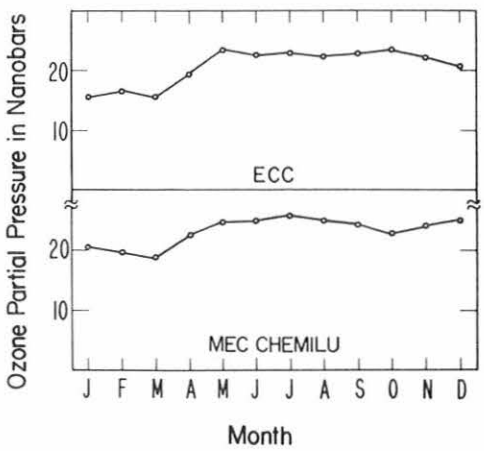


Figure 15. Mean monthly surface ozone at South Pole in 1975.

the trend of the monthly mean results near the end of the period (November and December) even though both instruments appeared to be respond similarly to the day-to-day variations.

The monthly mean surface ozone data for all of the observing locations are plotted in Figure 16 for the period 1973-1975.

CALIBRATIONS

With the introduction of the Dasibi ozone photometer into the surface ozone network, it was discovered that the McMillan Electronics Corporation (MEC) Model 1000 ozone generator was inadequate as a secondary calibration standard because of defects in its design. A major defect was the use of ozone-destroying materials in the construction of the generator's air flow system, which rendered the unit incapable of providing a stable source of ozone over an extended time period. Because of inadequate filtering of incoming air, the generator was also found to be a source of particulates which interfered when the reference gas from the generator was sampled by a Dasibi ozone meter.

Our MEC ozone generators have been extensively modified recently to overcome the defects described above, and now appear to work satisfactorily as secondary ozone standards. A block diagram of a modified generator is shown in Figure 17, the major modification being incorporation into the instrument of a double quartz tube reaction chamber in which ozone is produced photometrically without partial destruction by wall effects.

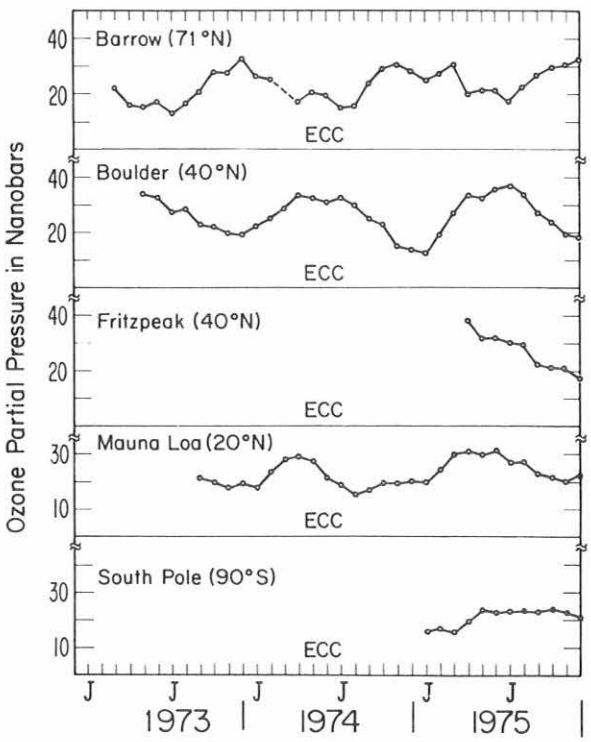


Figure 16. Monthly surface ozone.

Generators calibrated against ECC Ozone Meter Model 001, Serial No. 001, have been deployed to each GMCC location for use in checks every 2 weeks on the performance of both the ECC Ozone Meter Model 005 and Dasibi ozone photometer.

A remaining problem in using MEC generators as accurate secondary standards concerns the development of corrections for changes in generator output due to changes in atmospheric pressure. The generators are normally calibrated at one pressure but are used at a far different pressure--that prevailing at the observing station. To date, the pressure corrections have been determined by measuring the ozone output of the generators at Boulder (average pressure 834 mb) and at Fritz Peak Observatory (average pressure 730 mb), and extrapolating the results to the pressure of the observatory where the generator is to be used. A preferable procedure would involve the use of an environmental test chamber where the ozone ouptut of the generator could be measured at the appropriate pressure. Such a chamber has been purchased but was not available for use during 1975.

INSTRUMENTATION

The ultraviolet absorption ozone photometer was added to the inventory of analyzers making surface ozone measurements at the GMCC locations. This instrument, manufactured by the Dasibi Environmental Corporation of Glendale, California, will be used alongside the ECC Model 005 meter at all of the GMCC locations. It will replace the chemiluminescent analyzer at the South Pole Observatory.

The design of the Dasibi ozone photometer is based on the absorption of 253.7-nm wavelength light by ozone. The photometer comprises a monochromatic UV source, a sample chamber, a UV detector, and a signal processing and readout system. Two reference subsystems provide stability by correcting for source intensity, optical path transmittance, and detector response changes.

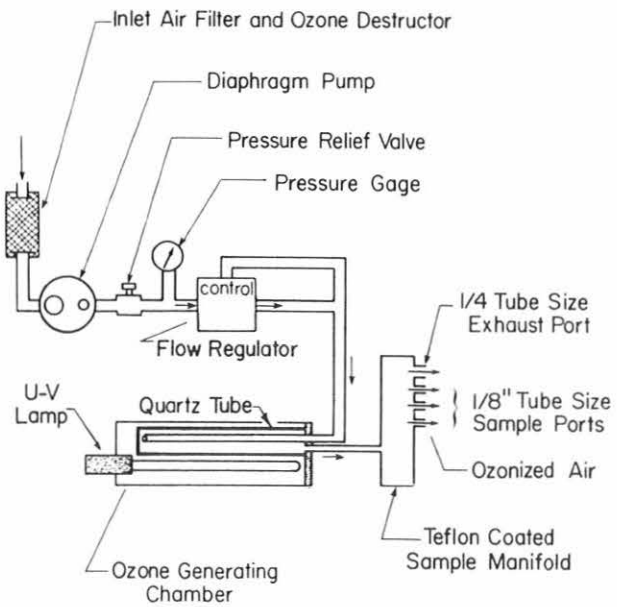


Figure 17. Diagram of the McMillan ozone generator (modified).

The block diagram of Figure 18 illustrates operation of the instrument. After entering the instrument the sample is diverted by means of a gas valve into the selective gas filter in which the active catalyst (manganese dioxide) converts all ozone to oxygen. The ozone-free air sample then passes through the absorption chamber where a detector measures the amount of ultraviolet light transmitted through it. This information is then stored digitally in the instrument to serve as a reference measurement since it represents absorption by trace substances other than ozone present in the air. Upon completion of this measurement, the gas valve is activated to allow ambient air to enter the photometer's absorption chamber. The amount of ultraviolet light, now reduced because of the presence of ozone, is again detected and stored digitally. The first measurement is then subtracted from the second to yield to the corrected ambient ozone background value.

The basic equation applicable to the Dasibi ozone photometer is:

$$I = I_0 \, e^{-\sigma_\lambda \, n_3 t} \qquad (1)$$

where I_0 is the initial intensity of the 253.7-nm light given off by the ultraviolet lamp, I is the final intensity, σ_λ is the ozone absorption cross section for the wavelength λ = 253.7 nm, n_3 is the number of ozone molecules in the path length, and t is the path length (71 cm). Digital readout on the instrument is provided in units of ozone mixing ratio (parts per million by volume) applicable to standard (0°C, 1 atmosphere pressure) operating conditions. Ozone amounts in units of ozone partial pressure at ambient pressure and temperature conditions can be computed from

$$P_3 \text{ (nb)} = 172 \cdot T \cdot \log_e \left[1 - 10^4 \cdot \frac{\text{OUTPUT}}{\text{SPAN}}\right] \qquad (2)$$

where T is the operating temperature of the instrument in degrees Kelvin, OUTPUT is the digital display readout, and SPAN is a digital count proportional to I_0 in equation (1) that allows scaling of the OUTPUT. SPAN is

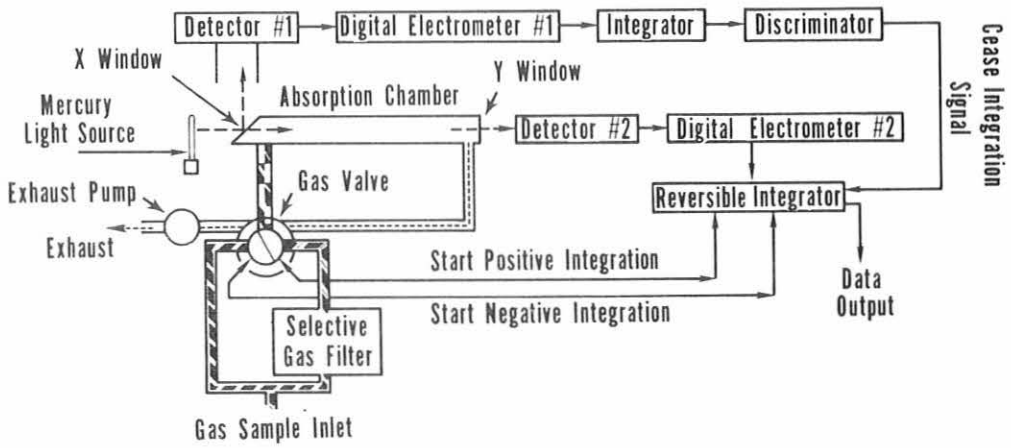


Figure 18. Diagram of the Dasibi ozone monitor.

normally set at a value of 520,000 counts so that the display then reads out the approximate ozone amount directly in partial pressure, although in the somewhat unwieldy units of 10^3 nanobars (1 microbar).

4.1.4 Halocarbons

PROGRAM

Although the project leader for the GMCC Freon-11 program relocated to the Techniques and Standards Group in 1974, actual flask preparation and analyses were continued at the Air Resources Laboratory's Field Research Office at Idaho Falls, Idaho, until the middle of May 1975. Sampling continued at Barrow, Mauna Loa, and Samoa with stainless steel flasks. Outlined below are the operating conditions of the Electron Capture Chromatograph used at Idaho Falls to analyze the flask samples:

Detector:	15 milicuries Nickel 63
Detector Temperature:	30°C
Column:	10'x¼" Carbowax 400/Porasil F
Column Temperature:	30°C
Carrier Gas:	Ultra-pure nitrogen
Flow Rate:	50 cc/min
Electronics:	Fixed pulse mode
Pulse width:	2 microseconds
Pulse period:	200 microseconds
Pulse height:	-20 volts
Sample Volume:	5 cc

A Hewlett-Packard variable frequency gas chromatograph was received in April 1975 and put into operation at the Techniques and Standards Laboratory in Boulder, Colorado. The operating conditions of this instrument were:

Detector:	15 millicuries Nickel 63
Detector Temperature:	100°C
Column:	10'x1/8" Carbowax 400/Porasil F
Column Temperature:	40°C
Carrier Gas:	95% Argon--5% Methane
Flow Rate:	15 cc/min
Electronics:	Variable frequency mode
Sample Volume:	1 cc

Transfer of the complete halocarbon program took place in mid-May and the stations were instructed to send all exposed flasks to Boulder for analysis. Cross comparisons were made of the Idaho Falls system and Boulder system by analysis of the same samples at both locations.

As flasks were analyzed in Boulder, it became apparent that the sensitivity of the Hewlett-Packard chromatograph was too low because of certain limiting design features. For partial correction of this deficiency, the Idaho Falls detector and electronics were transferred to Boulder. A duplicate of the electronics was fabricated and, together with the detector, was

installed in the Hewlett-Packard chromatograph to continue the analysis. This configuration was used through the remainder of the year. The operating conditions were:

Detector:	15 millicuries Nickel 63
Detector Temperature:	150°C
Column:	10'x1/8" Carbowax 400/Porasil C
Column Temperature:	70°C
Carrier Gas:	Ultra-pure nitrogen
Flow Rate:	20 cc/min.
Electronics:	Fixed pulse mode
Pulse width:	2 microseconds
Pulse period:	200 microseconds
Pulse height:	-20 volts
Sample Volume:	1 cc

Tests on the Hewlett-Packard chromatograph were continued to determine whether the sensitivity of the instrument could be increased under variable frequency operating mode. The manufacturer has recommended certain electronic modifications to the instrument which will be attempted in 1976.

INSTRUMENT DEVELOPMENT

A. Gas Dilution Apparatus

The Idaho Falls chromatograph system was initially calibrated for Freon-11 on the basis of coulometry and this calibration was transferred to Boulder by sample comparisons. A number of errors can arise using such an approach. Implementation of an independent calibration gas method was, therefore, considered.

Because of simplicity of design, a static gas dilution system was built. In the design stage, the virial coefficient gas law was used and an error analysis made using manufacturer's commonly quoted accuracies and precisions for temperature and pressure measurements. A schematic diagram of this system is shown in Figure 19.

The operational procedure is for pure Freon-11 (sample) gas to be introduced into an evacuated volume of approximately 10 cc where the gas is isolated and its temperature and pressure measured. The small gas volume is now expanded into a large volume of 10,000 cc and a dilution gas introduced. Temperature and pressure are again measured. With the resulting 1000:1 volume ratio and a 10:1 pressure ratio, a dilution of 10^4 is possible. If the mixture is then reintroduced into the smaller volume and the large volume again evacuated, the procedure can be repeated again and again to reach any desired sample gas concentration.

During December several attempts were made to achieve a three-stage dilution into the parts-per-trillion range using fluorocarbon-11 and nitrogen. Successive batches of the gas mixtures did not show repeatability, probably because of container wall effects. Further tests are in progress.

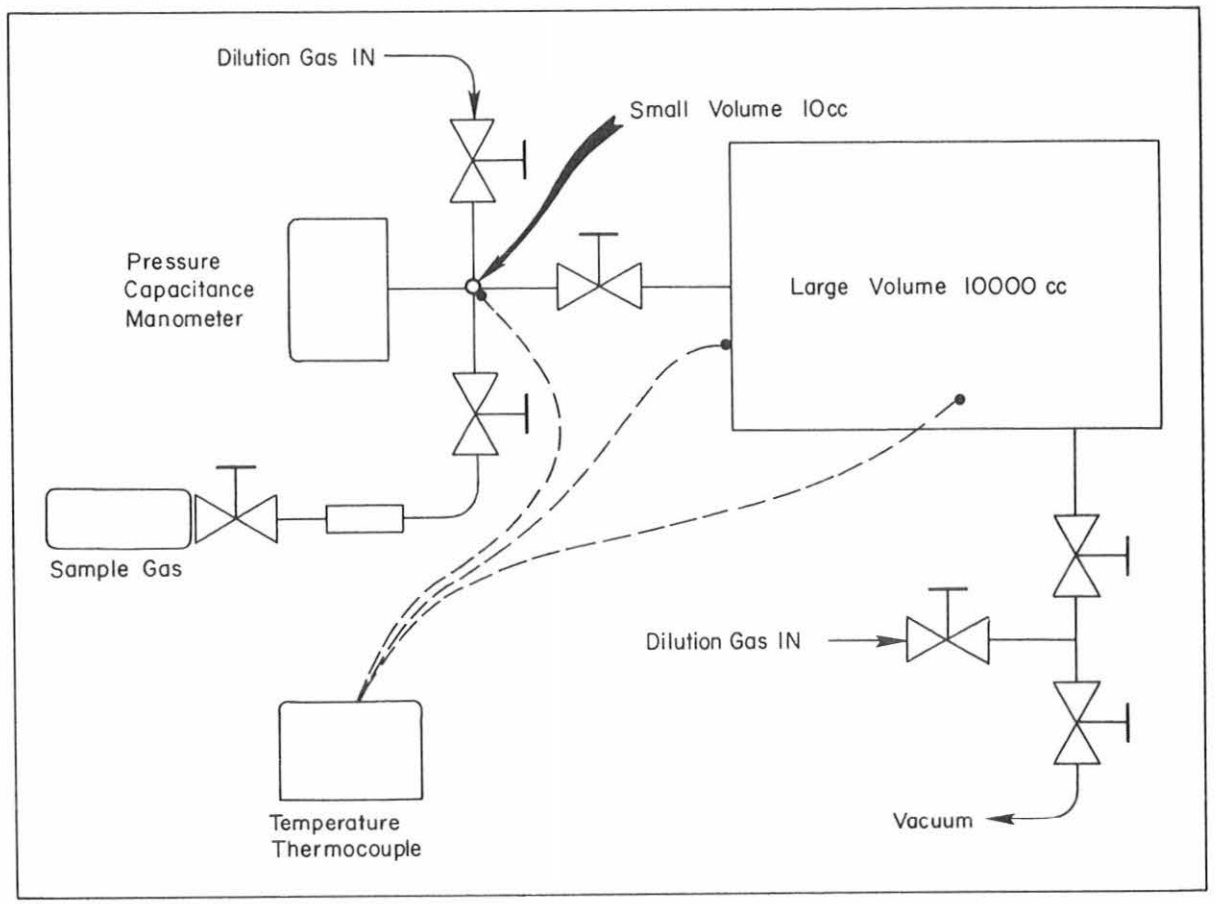


Figure 19. Diagram of gas dilution apparatus.

B. Cylinder Pump-Up System

A preponderance of apparently contaminated (high-reading) fluorocarbon-11 samples collected at the GMCC field stations during 1975 indicated the need for an improved sampling technique. To eliminate problems inherent in sampling with stainless steel flasks, a decision was made to collect air samples pressurized to an overpressure of about 10 psi above ambient air pressure. A prototype flask pump-up apparatus, shown in Figure 20, was therefore built and tested. First field use of the unit will be at South Pole Station in January 1976.

DATA

Table 10 lists the halocarbon-11 (CCl_3F) concentrations determined from flask air samples collected at the GMCC baseline stations. Indicated standard deviations were determined from the spread in repeated sample analyses. The overall uncertainty in the concentrations is estimated to be ±25% except for data obtained during October, November, and December 1975 in which flask contamination may have caused the unexpectedly high concentrations. The problem is under investigation.

Table 10. 1975 Data Base CCl_3F

	BARROW			SAMOA			MAUNA LOA		
Month	Day	F-11 Conc. (ppt)	σ	Day	F-11 Conc. (ppt)	σ	Day	F-11 Conc. (ppt)	σ
Jan	16	120	5	4	155	7	3	142	4
	28	137	7	14	164	21	10	149	13
				21	941	44	17	118	14
				31	170	21			
Feb	11	143	13				3	113	8
	18	136	4				7	161	6
	26	112	15				19	114	7
							26	14628	221
Mar	4	108	2	13	92	10	5	97	3
	14	111	4	21	99	10	12	110	6
	18	102	2	31	106	7	19	115	4
	25	149	7				25	107	9
Apr	1	142	3	10	116	4	9	105	3
	15	99	8	18	145	10	16	1836	21
	25	114	7				23	99	4
							28	98	2
May	1	119	3	6	5153	--	2	114	5
	9	102	4	12	64	6	7	105	4
	13	155	3	20	108	8	13	100	7
	20	168	7				17	95	7
	27	95	6				21	82	10
							29	106	16
Jun	5	103	4	8	109	6	7	134	10
	10	106	5	8	83	5	12	85	10
				21	85	5			
Jul	15	147	9	12	781	13	1	776	24
	25	107	6						
Aug	3	117	15	1	260	7	8	185	22
	14	105	7	14	598	6	14	106	18
				22	233	9	21	278	20
							27	320	11
Sep	6	132	8	6	220	9	5	185	16
	16	203	6	13	681	16	11	225	31
	26	220	9				18	243	4
							25	30353	--
Oct	1	128	8	2	503	7	2	147	7
	10	540	10	10	220	11	9	346	12
	14	231	5	18	415	12	16	371	21
	23	202	11	31	307	3	24	331	5
Nov	12	272	6	8	284	1	6	370	8
	19	132	5						
Dec	16	204	8	14	256	2			
	24	948	6						
	30	251	7						

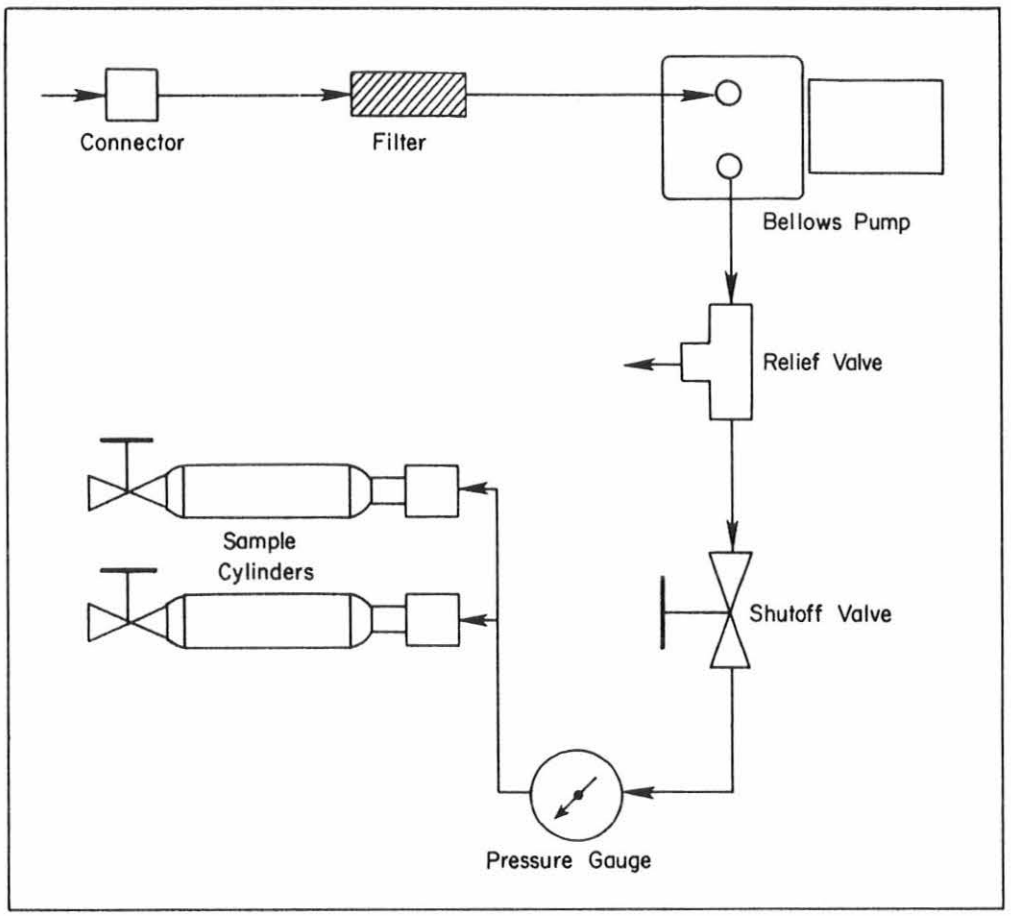


Figure 20. Diagram of cylinder pump-up system.

The 1975 data and all previously obtained data are graphically displayed in Figures 21, 22, and 23.

In a cooperative effort with Naval Research Laboratory, 18 stainless steel flask air samples were collected during Arctic flights in April and May 1975. CCl_3F analysis results for these samples are shown in Table 11.

4.2 Upper-Air Measurements Using Lidar

4.2.1 Aerosols

A major activity during 1975 was the continuing study of the enhanced stratospheric dust layer caused by the eruption of Fuego volcano in Guatemala during October 1974 (Fegley & Ellis, 1975) Observations were made during the evening hours, one day per week. Although this event was less significant in terms of stratospheric enhancement than the Agung volcano eruption during the

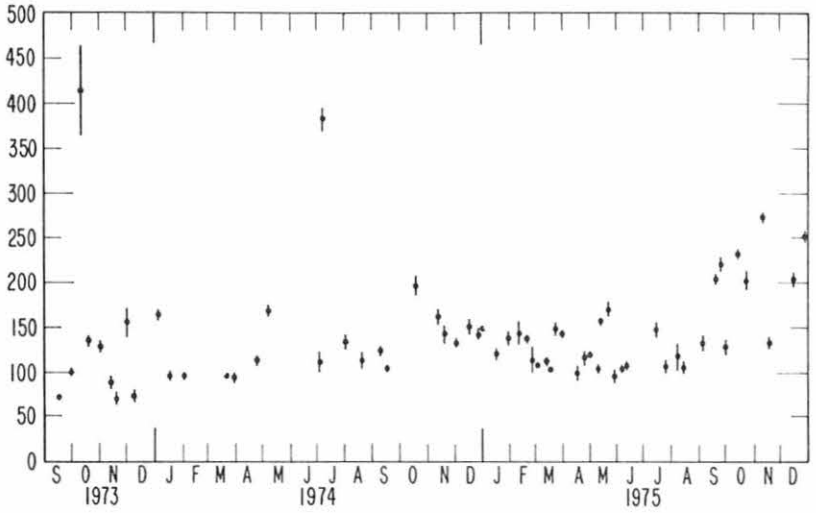


Figure 21. CCl_3F data for Barrow, Alaska.

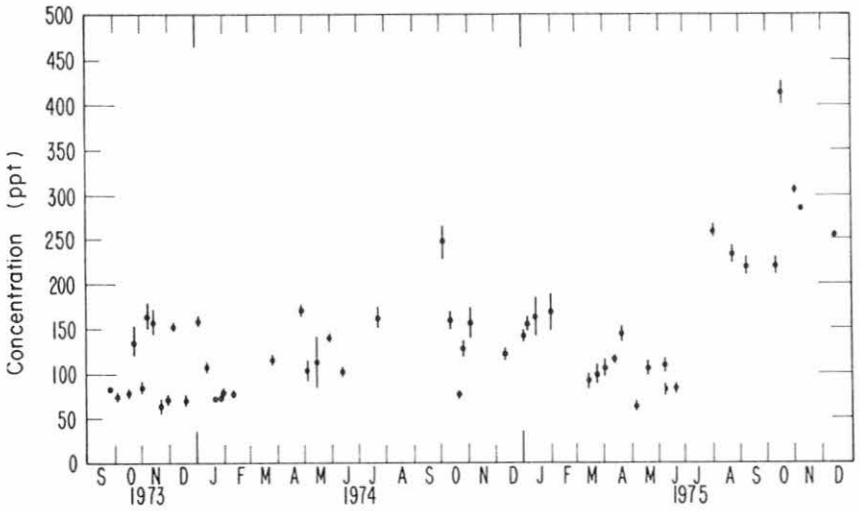


Figure 22. CCl_3F data for Cape Matatula, Samoa.

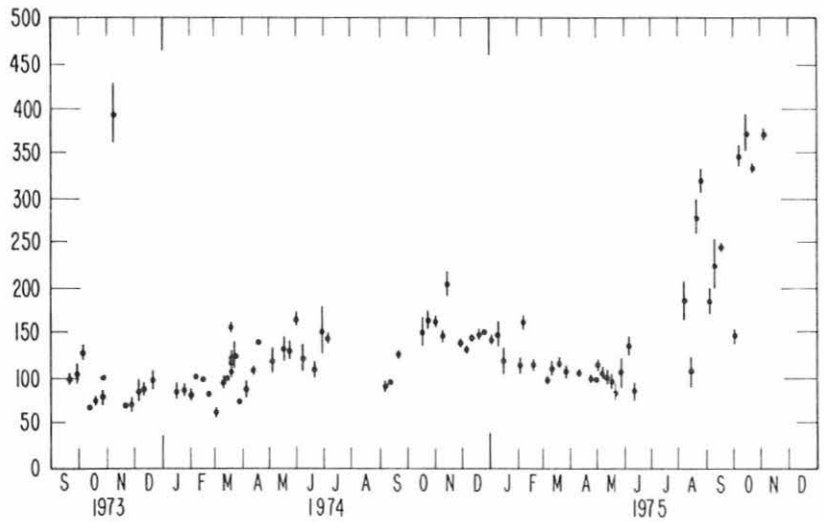


Figure 23. CCl_3F data for Mauna Loa, Hawaii.

Table 11. CCl_3F Values from NRL Cooperative Program

Date 1975	Sample No.	Altitude (feet)	F-11 Conc. (ppt)	Position
4-17	2	1000	110.2	85°46'N 40°00'W
17	4	1000	103.5	84°39'N 67°12'W
18	6	1000	90.2	85°48'N 20°49'W
18	8	1000	970.8	85°25'N 40°33'W
19	10	1000	107.5	85°29'N 25°26'W
21	12	1000	94.1	85°09'N 24°39'W
23	14	1000	105.4	81°39'N 61°57'W
28	19	1000	108.9	82°55'N 58°46'W
29	22	1000	98.5	87°14'N 25°28'W
5- 1	25	1000	131.1	87°25'N 27°42'W
2	27	22000	86.3	82°37'N 56°55'W
2	29	1000	113.2	86°07'N 77°58'W
2	31	27000	78.9	86°10'N 44°52'W
3	33	1000	111.6	86°11'N 87°03'W
5	35	1500	111.6	84°03'N 48°03'W
5	37	20000	101.9	89°29'N 28°22'W
5	39	20000	61.3	87°46'N 18°44'E
5	41	1000	116.9	82°56'N 20°08'E

mid-1960's, it remains one of the better studied events by the use of advanced monitoring systems such as lidar and stratospheric research vehicles (Rosen et al., 1975; Elterman, 1975).

Figure 24 summarizes the 1975 study of the Fuego event. It is a plot of the integral of the backscatter coefficient throughout the depth of the stratospheric cloud. Weekly values are shown rather than monthly averages. The dust layer first appeared at Mauna Loa on October 8, 1974, as a clearly defined layer slightly above the tropopause. Its intensity increased such that by November 5 the layer was easily visible to the eye as a widespread cirrus-like layer. As the layer continued to diffuse both horizontally and vertically, it became less prominent. (Originally the layer was less than 1 km thick but gradually thickened to 3 to 4 km toward mid-1975.) The layer was much more horizontally uniform after about March 1975 and generally weakened until finally resembling the normal Junge layer of late 1973. During 1974 the stratosphere had become extremely clean with scattering ratios

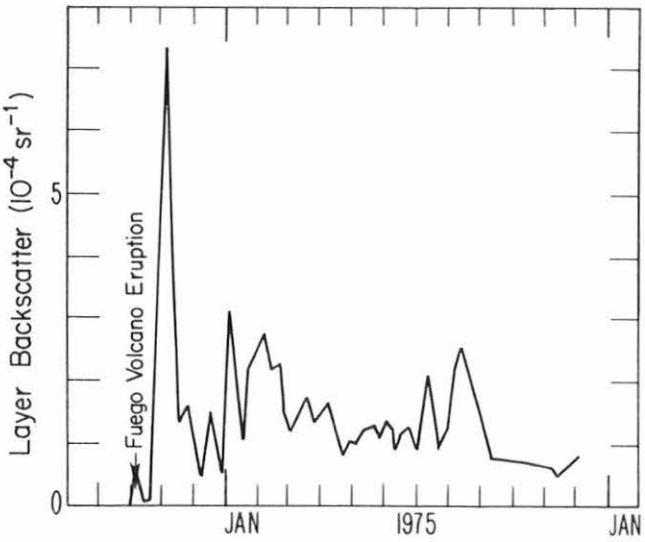


Figure 24. Total backscatter of the Fuego dust cloud above Mauna Loa Observatory.

approaching 1.05 or so in September. This points out that during the period from early 1973, when lidar measurements were first initiated, to October 1974 the stratosphere was still in the process of cleaning itself from previous dust injections.

The second major peak shown in Fig. 36 of Summary Report 1974 has been identified as faulty data. This discovery has simplified the interpretation of the entire event.

During 1975 an attempt was made to extend the aerosol studies down into the troposphere. Fig. 25 displays the average aerosol backscatter coefficient for three altitude regions. In the 13-15 km region, which is just beneath the standard tropical tropopause, the aerosol backscatter coefficients were much higher during the spring and early summer than at other times. The length of the data record prevents a determination of whether this is a seasonal effect or associated with the transfer of Fuego aerosols from the stratosphere into the upper troposphere. Analysis of the 1976 data should clarify this point.

The region between 19-21 km shows the gradual decreasing trend from early 1973 to late 1974 followed by sudden increase due to the Fuego injection and a subsequent decline.

The 21-23 km region shows a slight decreasing trend prior to the eruption, subsequent increase, and return to lower levels. On the basis of this information, there appears to be no obvious upward transport of stratospheric aerosols.

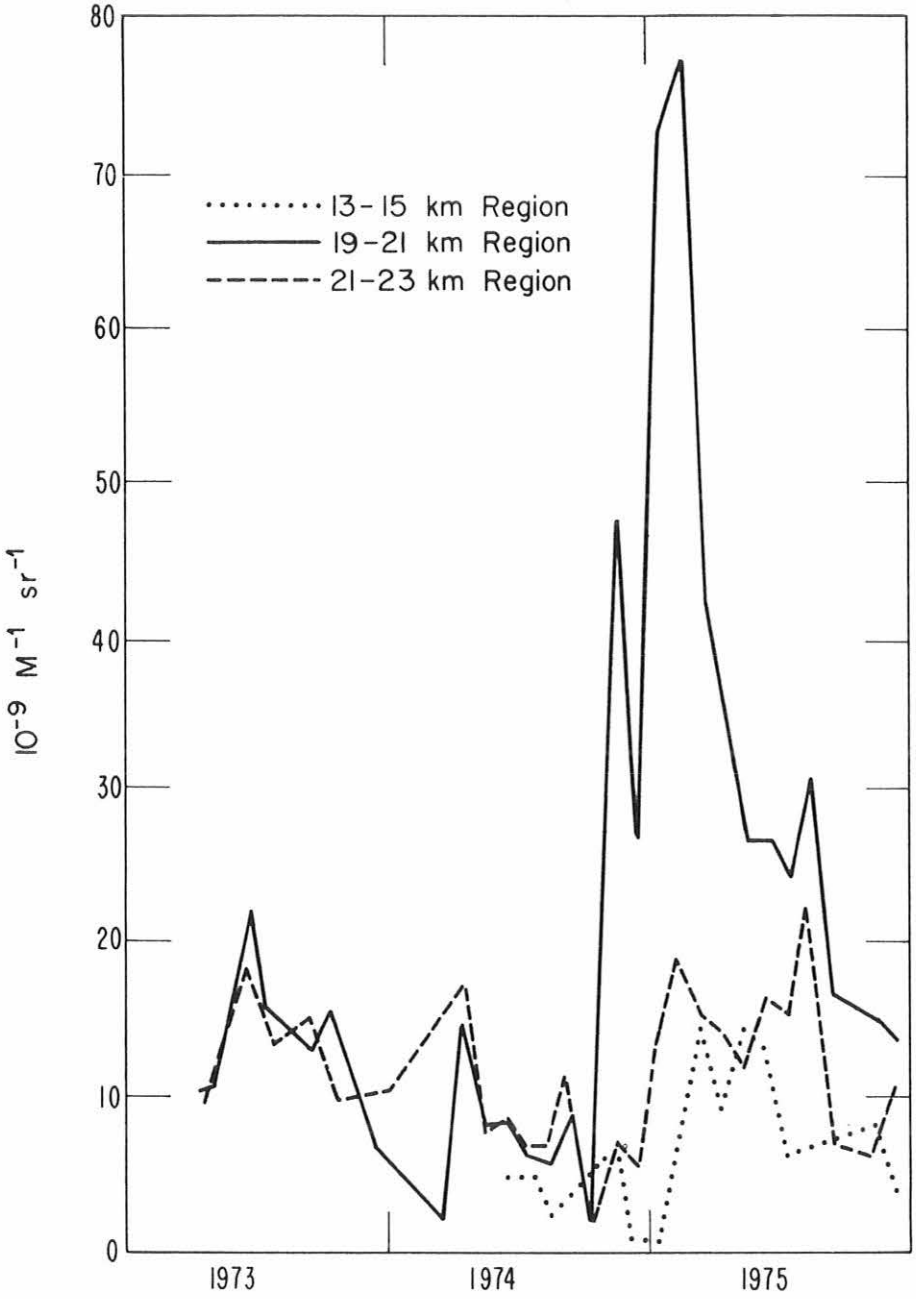


Figure 25. Monthly averages of the non-Rayleigh backscatter coefficient at different elevations above the Mauna Loa Observatory.

In general, the result from one evening of lidar observations is a profile of aerosol backscatter coefficient from 13 to 25 km MSL with a normal height resolution of 300 m. Fig. 26 shows typical profiles taken during 1975. By April 9 the stratospheric dust cloud, located at approximately 20

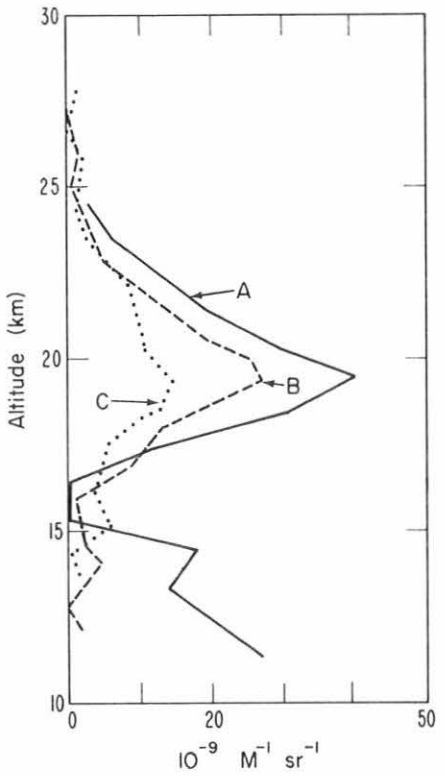


Figure 26. Typical Rayleigh backscatter coefficient profiles above Mauna Loa Observatory.

A--April 9

B--June 25

C--December 10

km had diffused considerably in vertical extent and had reached its maximum average reflectivity. It is interesting to note that the upper tropospheric aerosol concentration was higher than it has been observed at any other time, for which we have no explanation. By June 25 the dust cloud had become much reduced in total reflectivity. The tropopause, located near 16 km, shows a local minimum in aerosol concentration and the aerosol concentration below the tropopause remains at extremely low values. On December 10 the dust cloud was more ragged and further reduced in aerosol concentration. The relative minimum in aerosol concentration is located slightly below the tropopause.

Emphasis will be placed on extending the profiles to lower altitudes during 1976.

4.2.2 Clouds

Since early 1973 when lidar studies were first initiated at Mauna Loa Observatory, it has been apparent that useful cloud information in the upper troposphere would be a natural by-product of the lidar studies. It is known that the presence of cirrus cloud layers in the high troposphere can have substantial effects on the Earth's radiation budget. However, reliable information on the spatial, temporal, and optical properties of these cloud layers has been lacking in the past. By use of lidar, it is possible to measure the height and thickness of cirrus layers and, in principle, it should often be possible to calculate the optical thickness at the laser wavelength.

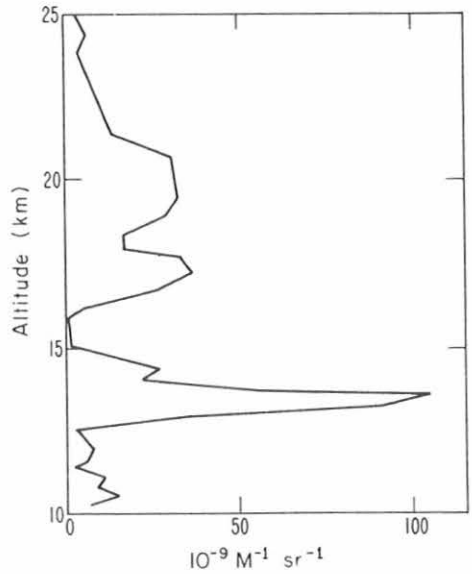


Figure 27. Non-Rayleigh backscatter coefficient profile for Mauna Loa, May 12, 1975. Note cirrus layer at 13.5 km.

Fig. 27 shows a 15-minute average of a cirrus cloud in a typical lidar analysis. The cloud was located at about 13.5 km and had a thickness of approximately 1 km. It is hoped that a complete analysis of all lidar cloud data from early 1973 will be completed in 1976.

4.2.3 Barrow System

In early 1975 a decision was made to expand the lidar program by installing a system at Barrow, Alaska, to provide needed information on atmospheric scattering properties for Northern Hemisphere regions. Although somewhat smaller, this lidar system will be similar to the Mauna Loa system. It will be located in a 2.5-m-square wanigan near the GMCC Observatory. Work during the year focused on procuring the necessary components and setting up the system in a portable trailer at Mauna Loa so that its entire operation can be checked before it is installed at Barrow.

SYSTEM DESCRIPTION

The transmitter portion of the laser system will be a 3-joule dye laser with a wavelength of 5900Å, transmitting at the rate of 3 pulses per minute. The receiver portion of the lidar consists of a 41-cm-diameter plastic Fresnel lens, a colored glass type filter, and a phototube. The optical system will be a collinear arrangement so that the laser and receiver beams will be overlapped to ground level, eliminating the near field effect.

The signals coming in from the phototube are digitized by a Biomation transient digitizer. They are then fed into a CAMAC system. This system utilizes a NOVA minicomputer for crate control and data processing functions.

Lidar operating programs and intermediate temporary data are stored on a cassette tape drive. Periodically, upon command from the ICDAS system, lidar results are sent along a send/receive line to the ICDAS in the main building for archiving. The CAMAC system will monitor the various functions of the transmitting and receiving systems and will control the entire lidar operation as well as shut the system down in the event of a system failure. Atmospheric profiles will be displayed on an oscilloscope for immediate operator interpretation as necessary.

The lidar system will initially operate continuously to provide profiles of aerosol concentration as well as low and high level cloud data. It may be slowed later to give lower time resolution and therefore extend the laser component lifetime.

4.3 Surface Aerosol Measurements

4.3.1 Mauna Loa

Short-tube Gardner counter SN826 was operated in January and long-tube Gardner counter SN1176 was operated through the remainder of 1975. Pollak counter SN13 was operated throughout 1975. Observations were taken hourly during the normal working day. Figure 28 shows monthly geometric means of Pollak counter observations. The daily upslope wind effect is clearly evident as shown by the high afternoon concentrations. However, there is no obvious annual trend in the 1000 LST readings, although it was expected that a trend with a peak in the summer would be observed because of the annual trend in lightscattering data obtained by the nephelometer. Overall, morning concentrations are fairly low, 200-250 CN cm^{-3}, representative of background conditions; the site cleanliness deteriorates with the afternoon upslope wind from below. Figure 29 shows the annual geometric means of the Pollak counter data.

Gardner counter SN1176 (long-tube) was calibrated by means of a two-month comparison with Pollak SN16 at Mauna Loa. Figure 30 shows the results of this comparison along a least-squares fit of Hoerl's equation:

$$\log y = a + b \log x + cx.$$

A calibration table for Gardner SN1176 was then generated to convert the Gardner scale divisions to nucleus concentrations.

A General Electric Condensation Nucleus Counter was installed at Mauna Loa in the summer of 1975. Although there were several short periods of reliable operation, in general the G.E. counter suffered from maintenance problems and few useful data were obtained.

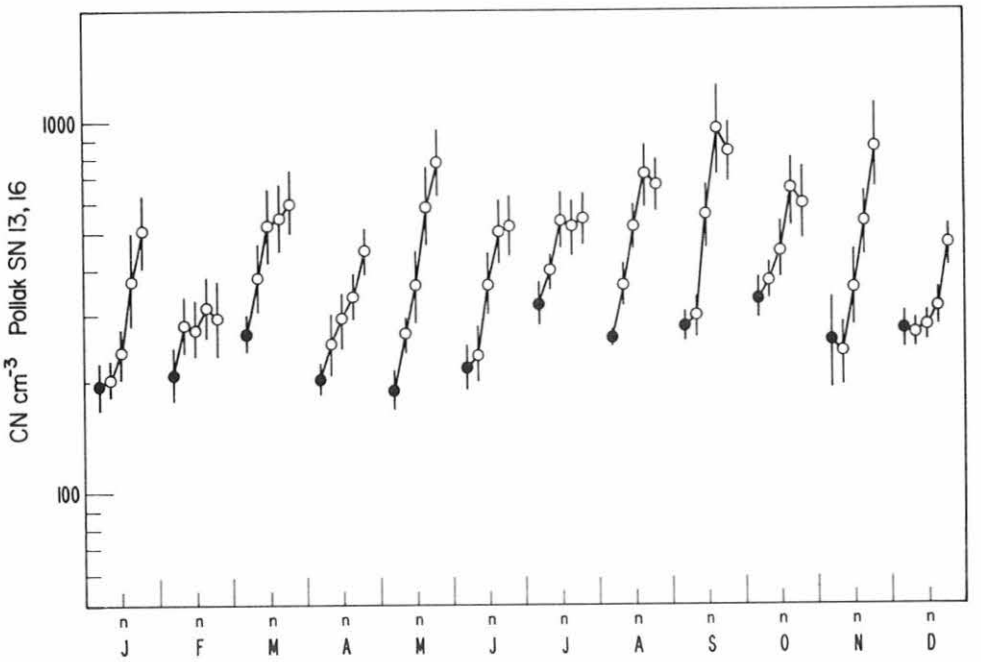


Figure 28. Monthly geometric means of condensation nuclei for 1975 at Mauna Loa Observatory, for 1000, 1100, 1200, 1300, and 1400 LST. The shaded dots indicate the 1000 LST values; n indicates the 1200 LST value; the vertical bars give standard errors about the mean (S.E. = $\sigma/\sqrt{n}$).

NEPHELOMETER

The Mauna Loa four-wavelength nephelometer operated reliably throughout 1975. Only six weeks of data were lost during the entire year. Furthermore, the instrument exhibited only nominal drift and the rather strict calibration schedule of a monthly Freon calibration and a weekly relative calibration proved more than adequate.

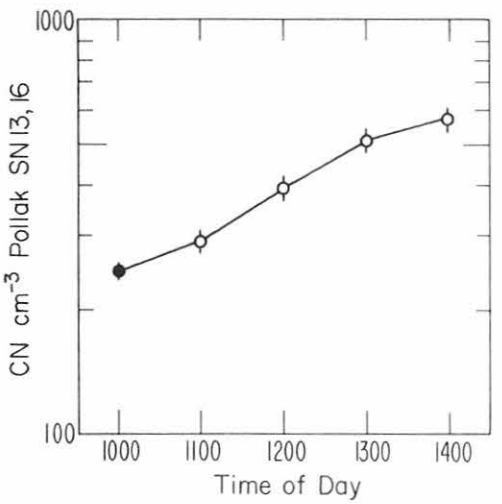


Figure 29. Annual geometric means of the hourly observations of condensation nuclei for 1975 at Mauna Loa Observatory. Vertical bars give standard errors about the mean (S.E. = $\sigma/\sqrt{n}$).

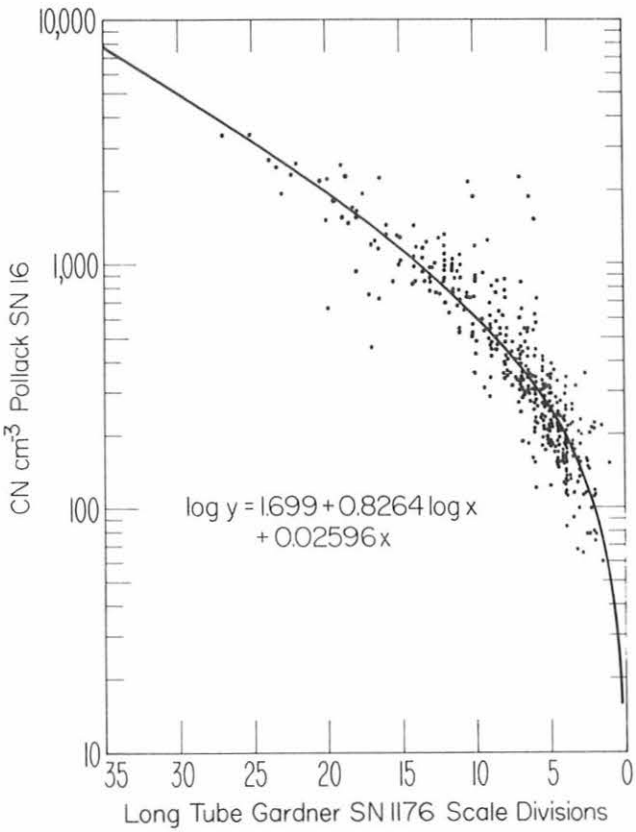


Figure 30. Comparison of long-tube Gardner counter SN1176 data with Pollak counter SN16 data on ambient aerosol at Mauna Loa Observatory during June and July 1975. The curve shows a least squares fit of Hoerl's equation.

Figure 31 shows means of hourly averages for selected months of 1975. All months show the usual diurnal effect and, in general, background light scattering is about an order of magnitude higher in the spring than in winter. However, note that the afternoon peak remains approximately the same throughout the year. The Angstrom exponent (α) shows rather large variations among the four selected months. In general, the small values of α in May indicate a tendency toward larger sized particles, whereas the large values of α in winter months suggest smaller sized particles. The odd behavior of the 850-nm curve in October is probably due to instrumental problems. The nephelometer is sensitive primarily to particles with radii of 0.1 to 1.0 μm.

Figure 32 shows the annual trend for light scattering at Mauna Loa. Each point is the geometric mean of the 0300 to 0400 LST hourly average for all days of each month. The seasonal trend is apparent with high light-scattering in the spring and very low or clean values in the winter. Furthermore, α shows erratic behavior during the spring and summer with a tendency toward larger sized particles, and fairly stable behavior during winter with higher values of α ($\simeq 2$) and a tendency towards smaller sized particles. The reason for this annual trend in background air is not entirely understood. However, it is probably due to a general increase of suspended particulate in the summer troposphere and to the motion of the atmospheric general circulation with season.

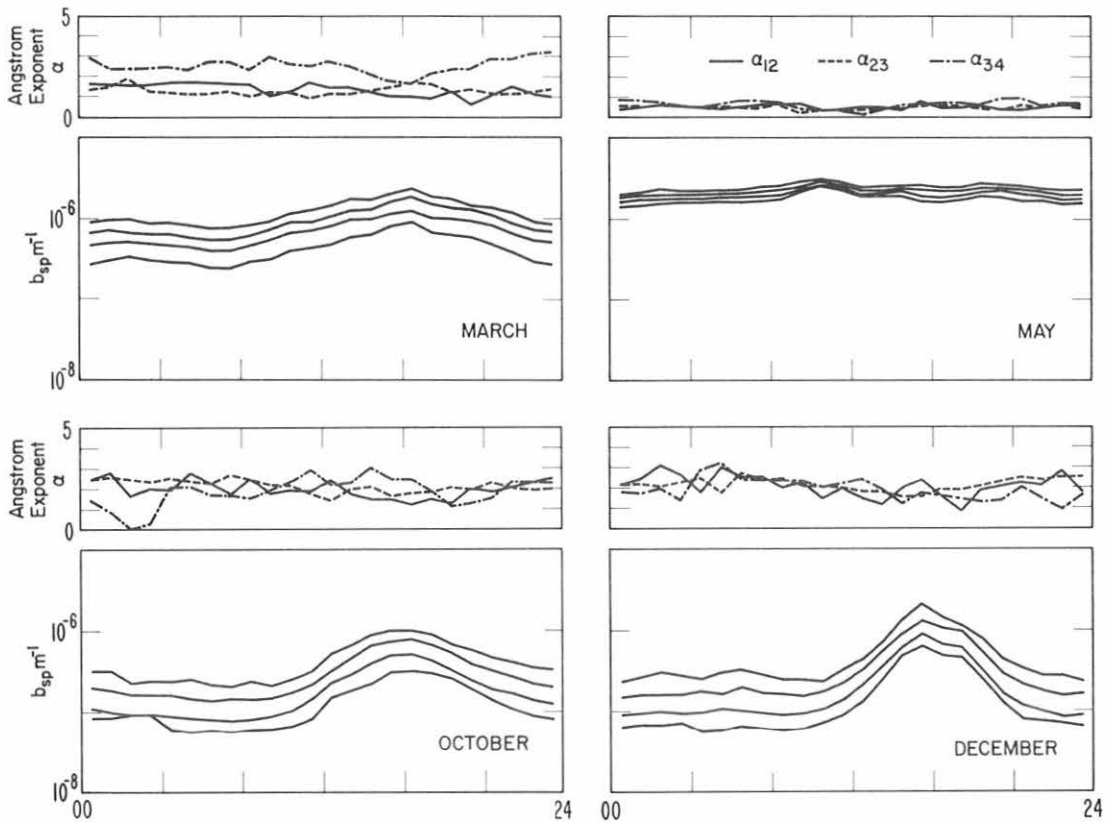


Figure 31. Monthly geometric means of hourly averages from the Mauna Loa four-wavelength nephelometer for 1975. The Angstrom exponent α_{12} is derived from 450 and 500 nm, α_{23} from 500 and 700 nm, and α_{34} from 700 and 850 nm.

To obtain a better understanding of these data it is useful to examine the continuous record and correlate it with local meteorological parameters. As an example, hourly averages of b_{sp} (550 nm) for October are given in Figure 33, along with hourly averages of relative humidity and wind speed and direction plotted at 3-hour intervals. A background level of approximately $10^{-7}m^{-1}$ is apparent with various perturbations superimposed. There is obvious correlation among the three parameters. Winds with an upslope (northerly) component are usually associated with high lightscattering values and downslope (southerly) winds produce the lowest lightscattering values. The classical upslope-downslope effect is clearly evident much of the time (e.g. Oct. 27-31) with high afternoon values of lightscattering, an increase in relative humidity, and a return to background conditions during nighttime hours. Also, during winter months, it is not unusual to encounter an extended period of strong southeasterly winds accompanied by low relative

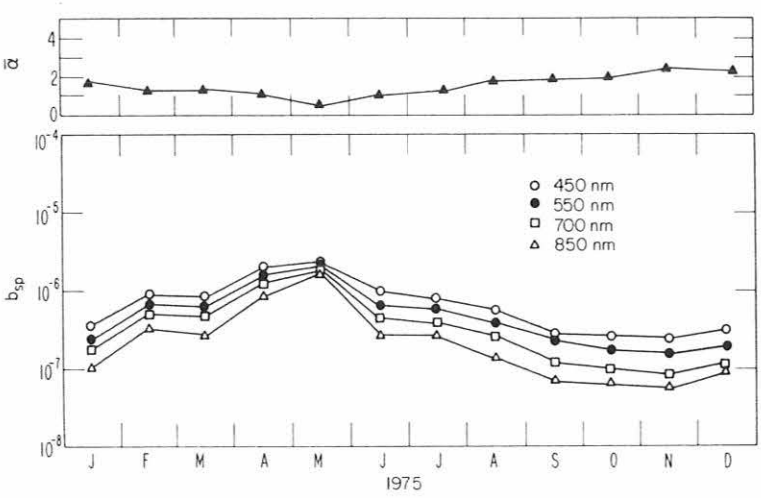


Figure 32. Monthly geometric means of lightscattering and Angstrom exponent for all 0300-0400 LST averages at Mauna Loa Observatory in 1975. $\bar{\alpha}$ is the average of α_{12} (450-550 nm) and α_{23} (550-700 nm).

humidity and extremely clean conditions (e.g. Oct. 1-5, 15-18, 23-28). These periods of high winds usually produce the lowest lightscattering values and often completely overpower the local diurnal wind circulation.

4.3.2. Barrow

Long-tube Gardner counter SN1143 was operated routinely throughout 1975. During January-April, a comparison was conducted on ambient aerosol between short-tube Gardner SN1098, which had been used during previous years at Barrow, and the new long-tube SN1143. About 400 comparison points were obtained and a least squares fit of Hoerl's equation was produced to give Figure 34. Although use of the short-tube Gardner was discontinued in favor of the more sensitive long-tube unit, with the comparison shown in Figure 34 previous data can be corrected to provide continuity across the transition.

In October 1975, Pollak counter SN16 was put into operation at Barrow. Previous to shipment, this Pollak was compared with Mauna Loa Pollak SN13 to produce the data shown in Figure 35. The least squares straight line shows excellent agreement between the two counters, especially between scale readings of 90 and 100 which correspond to nucleus counts of between 315 CN cm^{-3} and 0. In this region, agreement between the two Pollak counters is considerably better than 1%.

From October 1975 to March 1976, a comparison between long-tube Gardner SN1143 and Pollak SN16 was conducted on ambient Barrow aerosol and the results, along with a least squares fit of Hoerl's equation, are shown in Figure 36. The curve serves as the current calibration for routine Gardner counts at Barrow and previous observations taken with short-tube Gardner

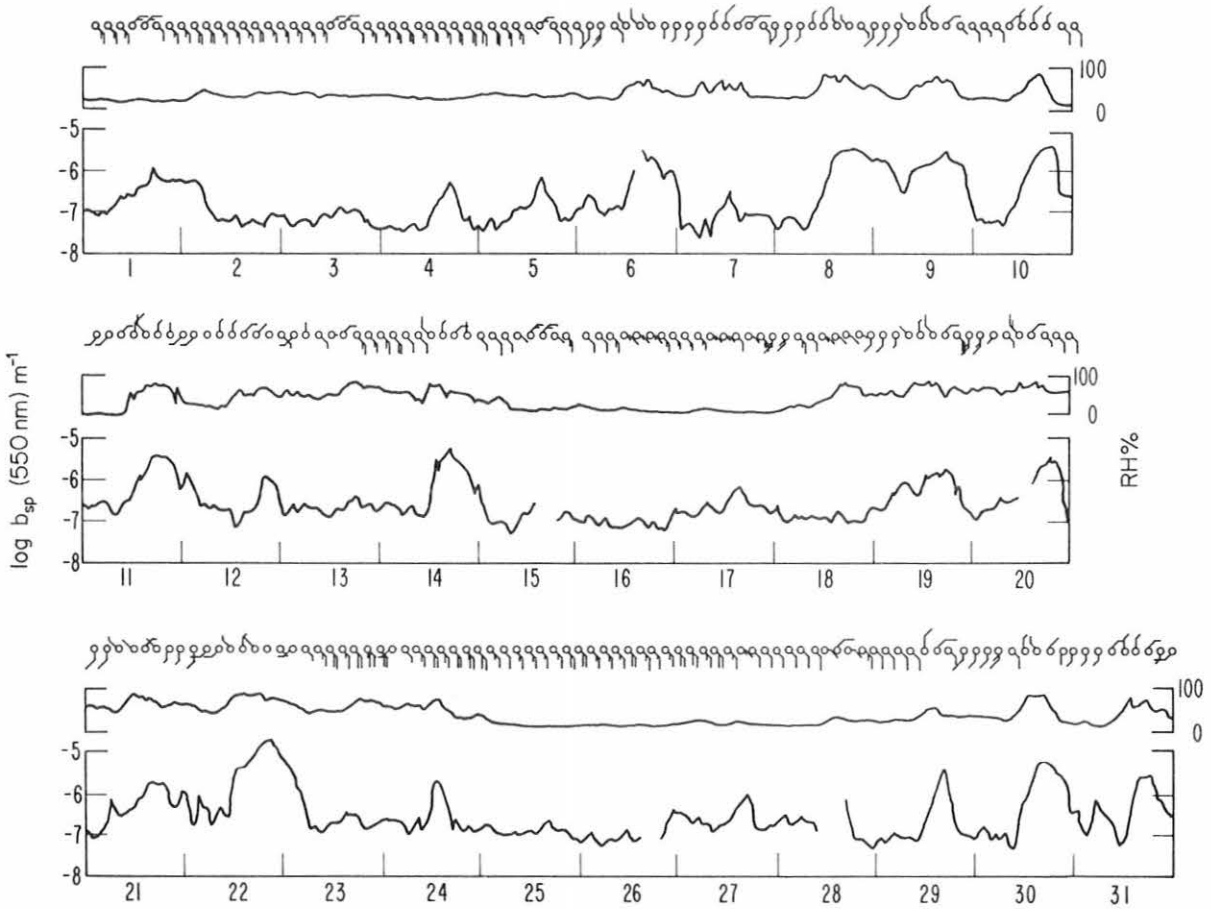


Figure 33. Hourly averages of 550-nm lightscattering and relative humidity at Mauna Loa Observatory for October 1975. Wind direction and speed at 3-hour intervals are shown.

SN1098 may be corrected by using Figures 35 and 36 or by a numerical solution of the two Hoerl's equations.

Figure 37 gives a wind rose and condensation nucleus geometric means as a function of direction for October-December. These data were taken with the Pollak counter. The mean concentration of 131 CN cm^{-3} for clean air directions is considerably less than concentrations measured in previous years because of the increased sensitivity of the Pollak counter and because a geometric mean is always less than an arithmetic mean. These differences will be reconciled in the future since all observatories are supplied with similar equipment and past data can be corrected in terms of current measurement techniques and updated calibrations.

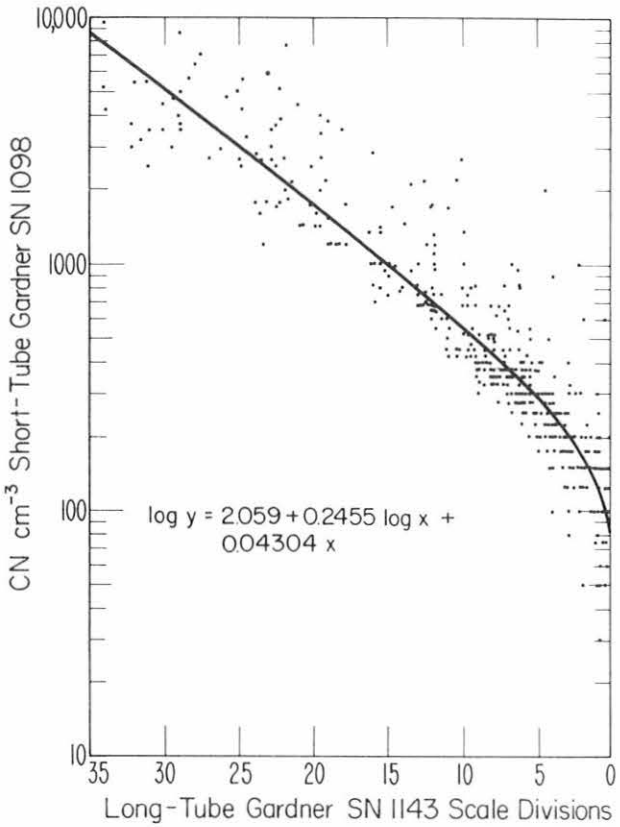


Figure 34. Comparison between short-tube Gardner SN1098 and long-tube Gardner SN1143 on Barrow ambient aerosol during January-April 1975. Curve shows least squares fit of of Hoerl's equation.

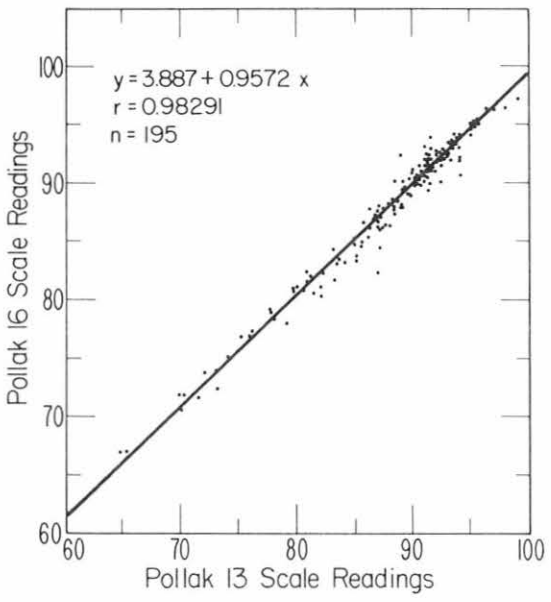


Figure 35. Comparison between Pollak SN16 and Pollak SN13 on Mauna Loa ambient aerosol during March and April 1975.

Table 12 gives monthly geometric means for 1975. Also given are the number of data points (n) and the logarithmic standard deviation for each mean (log σ). Overall, the Barrow observatory is a very clean site when the wind is from N, NE, E, or SE. However, the effects of fog and snow should be investigated more thoroughly to eliminate the effects of local scavenging which may produce unrealistically low nucleus concentrations.

4.3.3 Samoa

Because of the facility construction and its demand upon the GMCC observer's time, very few surface aerosol data were obtained from Cape Matatula during 1975. As no meaningful conclusions can be drawn from these data, they will not be presented.

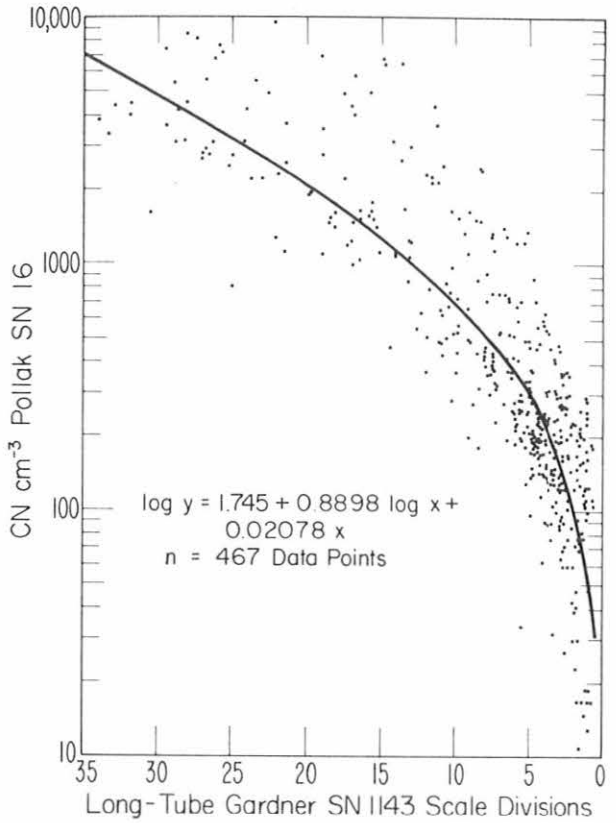


Figure 36. Comparison between long-tube. Gardner SN1143 and Pollak SN16 on Barrow ambient aerosol during October-December 1975 and January-March 1976.

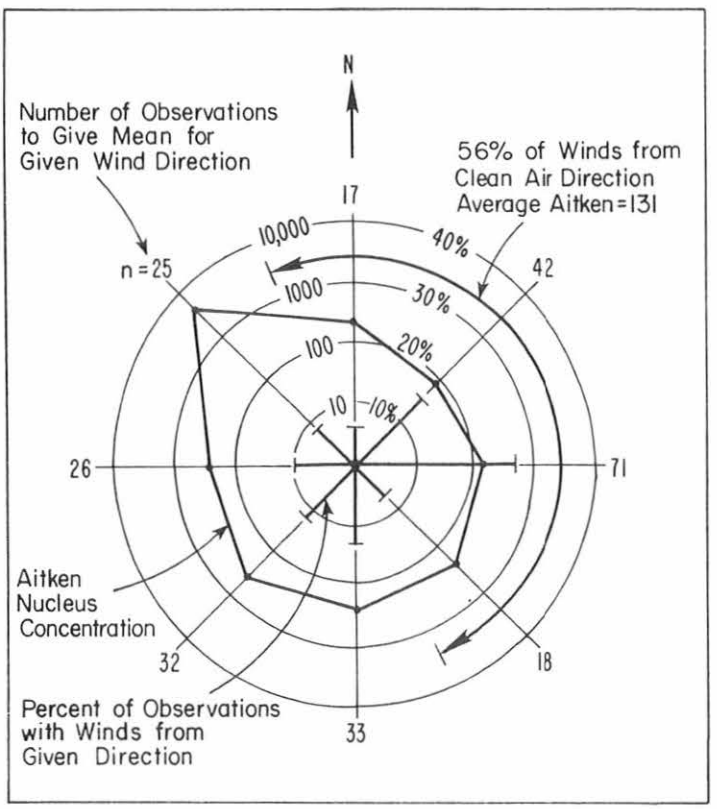


Figure 37. Barrow wind rose and condensation nucleus geometric means for October-December 1975.

Table 12. Monthly Geometric Means of Aerosol Measurements at Barrow

1975	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
$\bar{x}$	87	210	285	252	123	47	325	232	174	45	160	224
log σ	0.45	0.19	0.16	0.16	0.30	0.48	0.51	0.62	0.51	0.41	0.21	0.28
n	79	64	86	92	144	88	72	77	73	41	39	68

In CN cm^{-3}, for clean air direction (N-SE).

4.3.4 South Pole

Pollak counter SN15 continued to operate at South Pole station throughout 1975. Observations were obtained daily at 0100 GMT and 0800 GMT, during uncontaminated wind conditions, from the "clean air" facility at the new South Pole station. Sample air was brought into the instrument through the aerosol and gas sampling manifold designed for use at all GMCC sites. The manifold incorporates a high volume blower that draws air through a 6-in diameter stack and is distributed by means of isokinetic sampling probes to the various instruments.

Daily aerosol counts for August, September, and October 1975 are shown in Figure 38. Also shown are air temperature, wind speed, and wind direction at the time of the observation. Figure 39 gives the monthly geometric means of daily Pollak nucleus observations.

It is evident that very low condensation nucleus concentrations were encountered during the winter months with a low of about 10 CN cm^{-3} during July. As the austral summer approached, nucleus counts increased with a large jump in late September, about the time of sunrise. The very low concentrations during winter months are probably produced by removal forces acting beneath a strong temperature inversion that prevents mixing from aloft. Breaks in the inversion, accompanied by subsidence and photochemical processes, cause the increased values during summer months (Hogan, 1975; Hogan and Nelson, 1975).

The General Electric Condensation Nucleus Counter was modified and installed at Pole according to the design developed by the University of Washington and adopted for all GMCC observatories. In this configuration, the G.E. counter showed good stability and was sensitive to below 10 CN cm^{-3}. Continuous chart recorder data were obtained for all of 1975.

During 1975, long-tube Gardner counter SN1183 was present at Pole as backup for the Pollak or as a portable instrument for outdoor work. However, this instrument does not have sufficient sensitivity for nucleus observations at Pole. Thus the Pollak counter will continue as the standard observing instrument. Figure 40 gives the calibration curve obtained for Gardner SN1183 in a comparison with Pollak SN16 at Mauna Loa Observatory.

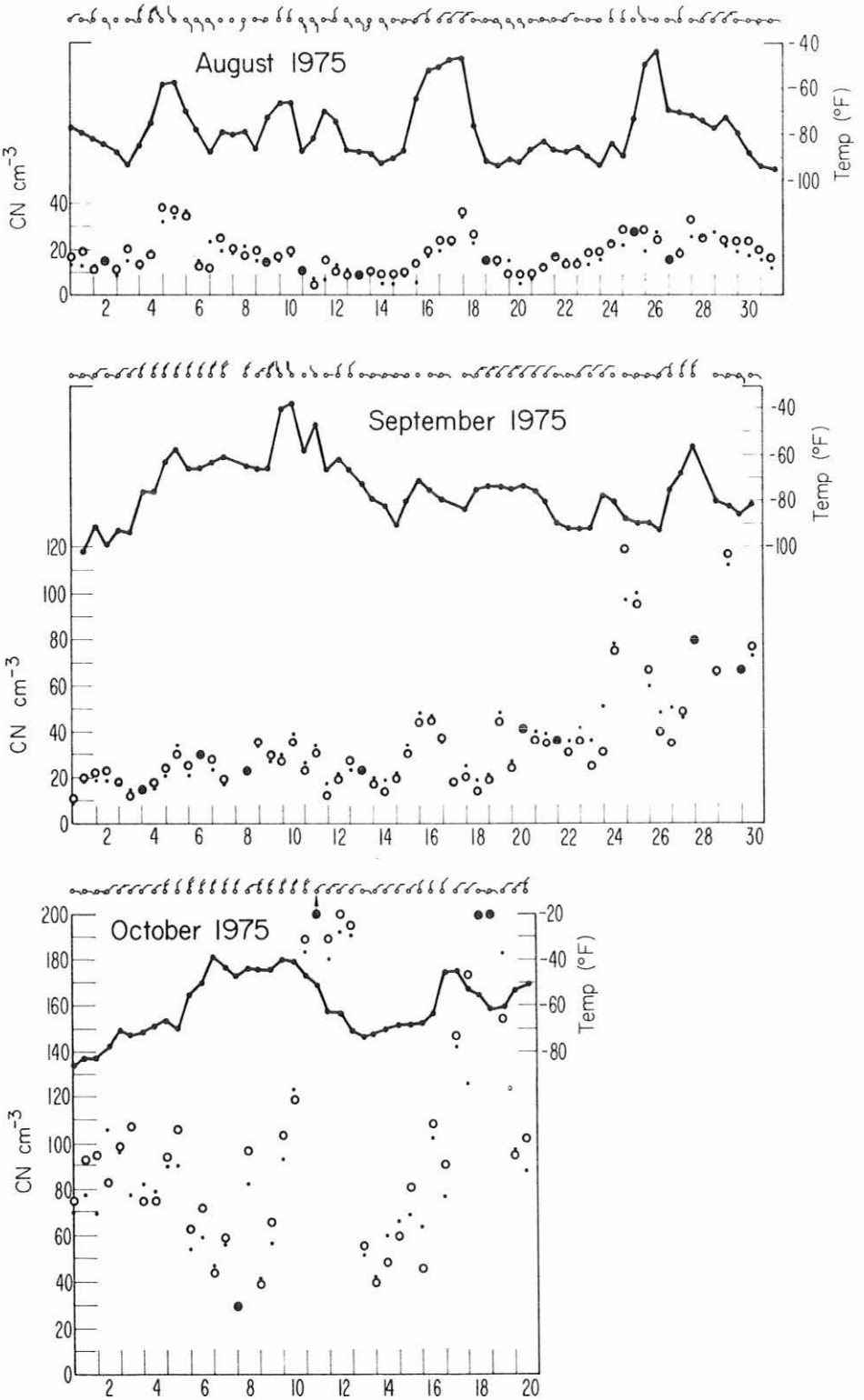


Figure 38. Condensation nucleus concentrations at South Pole for selected months of 1975. •, Pollak counter; °, G.E. counter.

Figure 39. Monthly geometric means of condensation nucleus concentrations at South Pole for 1975. Vertical bars give standard error of the mean (S.E. = $\sigma/\sqrt{n}$).

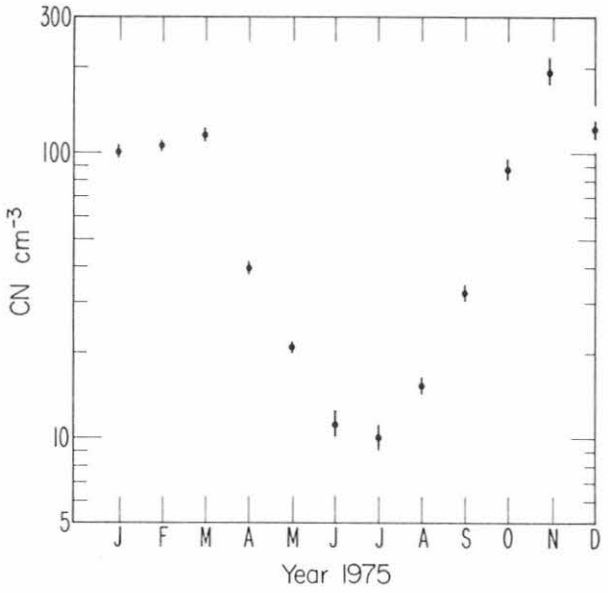
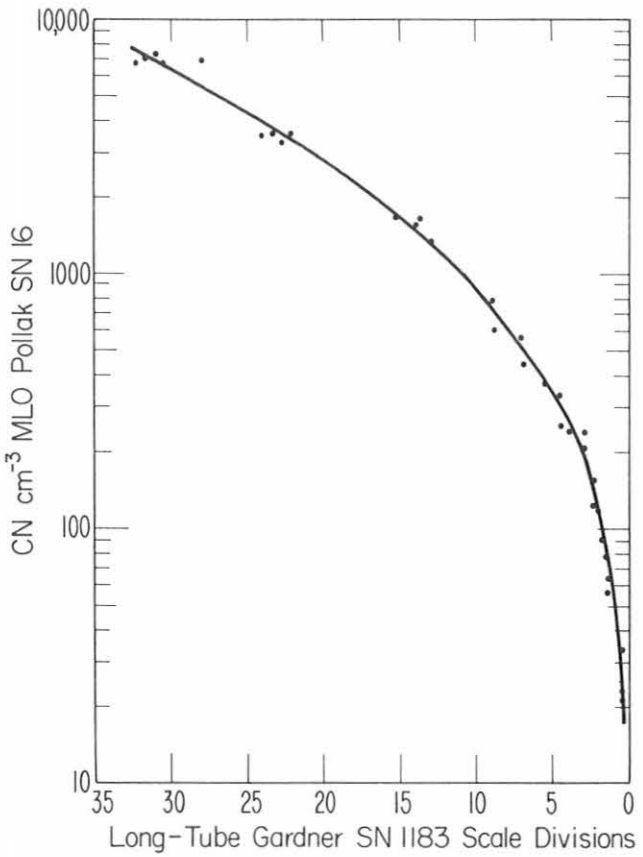


Figure 40. Calibration curve for long-tube Gardner counter SN1183 produced by comparison with Pollak SN16 at Mauna Loa Observatory.



4.4 Meteorological Measurements

4.4.1. Meteorological Sensors

In the past a wide variety of sensors have been used to measure wind, temperature, and pressure at GMCC observatories. Historically such measurements were initiated in support of a specific gas or aerosol monitoring program. In 1975 the measurements of wind, pressure, temperature, and humidity were standardized and sets of sensors were deployed at all stations. These sensors were supported by a set of translators that prepare the output for digitizing and recording.

With respect to wind, all stations except American Samoa had a propeller type anemometer installed at the time sampling started. Wind records are used to define periods when local air flow is from an established clean air sector. At all stations the anemometer is positioned at about the same height that gas samples are taken, usually between 10 and 16 meters above the surface. Wind speed and direction are recorded on a strip chart recorder to provide the observers a continuous visual display.

Fluctuations in station pressure as measured by local NWS stations would suffice to correct gas and aerosol measurements to standard pressure for all stations except the Mauna Loa Observatory. However, to determine the optical depth of the atmosphere a more accurate measurement of station pressure is required. Continuous measurements of station pressure are made with a static pressure transducer, (Fig. 41) to obtain a voltage that can be digitized, and with a microbarograph, for visual display. Both are calibrated twice a week with a mercurial barometer.

In addition to the general requirement for air temperature readings to correct gas and aerosol data to standard conditions, some sensors are temperature sensitive and specific response corrections must be applied. A linearized, thermistor composite was chosen as the sensor because its sensitivity makes it independent of line resistance. Liquid-in-glass thermometers are supplied to each station.

Relative humidity is measured except at South Pole where the humidity is below the detector's sensitivity. In addition to being an important factor in the operation of condensation nucleus counters, relative humidity is also an excellent indicator of upslope and downslope wind conditions at the Mauna Loa Observatory. The temperature and humidity sensors are exposed in an aspirated radiation shield which is mounted at or near standard shelter height, 2 to 3 meters (see Fig. 42). At the low-latitude observatories a hygrothermograph provides a backup to the electrical sensors in addition to a display of temperature and humidity to the observers.

Based on the program requirements (sensitivity, range, etc.), the following sensors were purchased and combined into a single meteorological system for use at each of the four field stations:

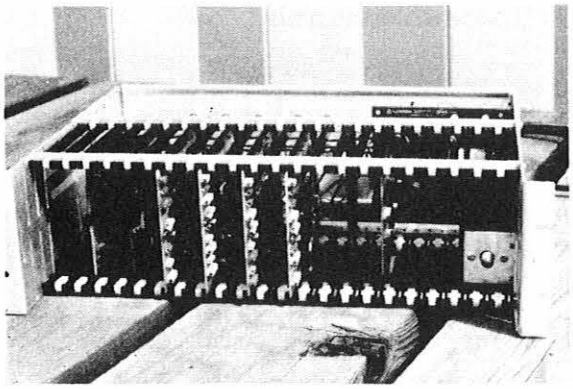


Figure 41. Translator crate to the meteorological sensors. It contains the printed circuit cards and power supplies to calibrate and scale the voltages from the sensors. The pressure transducer is mounted in the lower right.

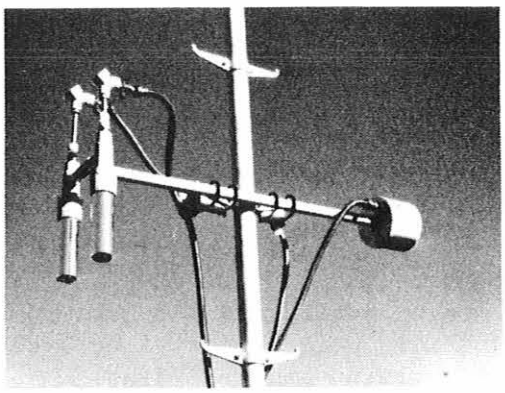


Figure 42. Aspirated radiation shields for both the air temperature and relative humidity sensors. The shields guarantee exposure error to be less than 0.1°C.

Wind speed and direction:	Aerovane Model 120, Bendix Corp.
Pressure:	Static pressure transducer, Model 1201C Rosemount Inc.
Temperature:	Linearized thermistor, Model 44212, Yellow Springs Instrument Co.
Relative humidity:	Model 1HM-111P humidicap, Helsinki.

Support electronics for these sensors are in the form of printed circuit cards. These, together with reference voltages, amplifiers, and power supplies are mounted in a translator case (Fig. 41). The voltages from all sensors are sampled once per second, and 1-minute and 1-hour averages are computed and recorded on magnetic tape in digital form by the Instrument Control and Data Acquisition System.

4.4.2 Mauna Loa Meteorology

Figure 43 shows the seasonal distribution of the wind direction and speed to a resolution of one month. In the two-dimensional plot the predominant wind direction, southeast, is seen as a constant feature throughout 1975. Another maximum is observed for the north and northeast directions during the summer months. The frequency of occurrence of calm conditions for each month is also presented. The average monthly percentage of calms in 1975 is 0.6 percent. Except in April and May the average wind speed of the southeasterlies is greater than 5 ms^{-1}. The average speed for the year 1975 is 4.3 ms^{-1}. The frequency of the wind direction and the average wind speed for each direction are also plotted. The maximum wind speed clearly corresponds with the predominant wind direction--southeasterly.

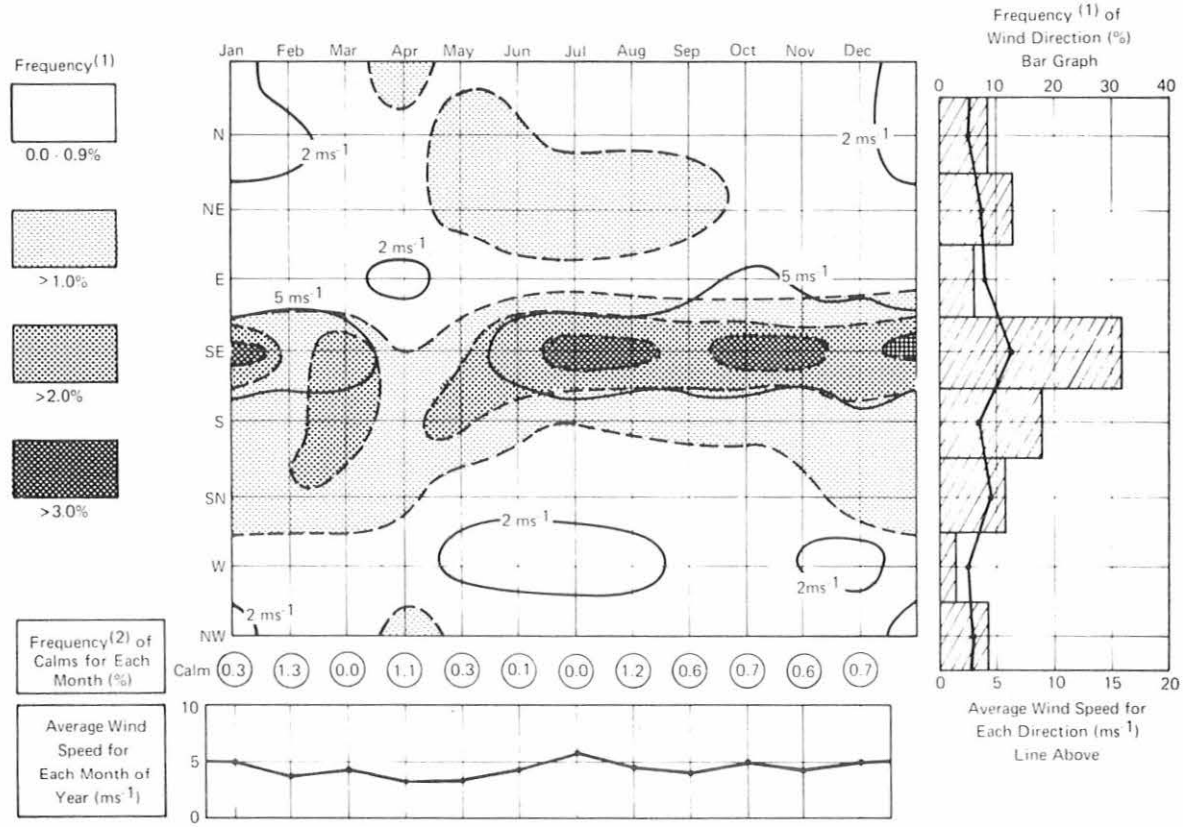


Figure 43. Surface wind data for Mauna Loa Observatory, 1975. (See legend, fig. 50)

HILO RAWINSONDE DATA

The pilot program started last year to evaluate upper air soundings taken at the Hilo Airport, 55 km northeast of the Mauna Loa Observatory, was extended through 1975. The upper air data were used to interpret the GMCC baseline data measured at Mauna Loa Observatory. Three sets of data were computer processed from the rawinsonde soundings: (1) twice-daily computations of total precipitable water above the elevation of Mauna Loa; (2) computations of the gradient (850 mb) and jet stream (250 mb) wind layers; (3) tabulations of daily tradewind temperature inversions and moisture cutoffs in relation to the height of the observatory.

Figure 44 is the plot of precipitable water in 1975 above the elevation of Mauna Loa Observatory. Maximum excursions of precipitable water occurred during the winter half of the year. These peaks of up to 12 mm are the results of synoptic storm passages over the islands when precipitation usually occurs. During the summer half of the year the trade wind inversion caps the moist maritime layer and dry conditions prevail above the observatory. The tradewind inversion, though not as persistent, is also present during the winter half and produces most of the dry conditions during this time of the

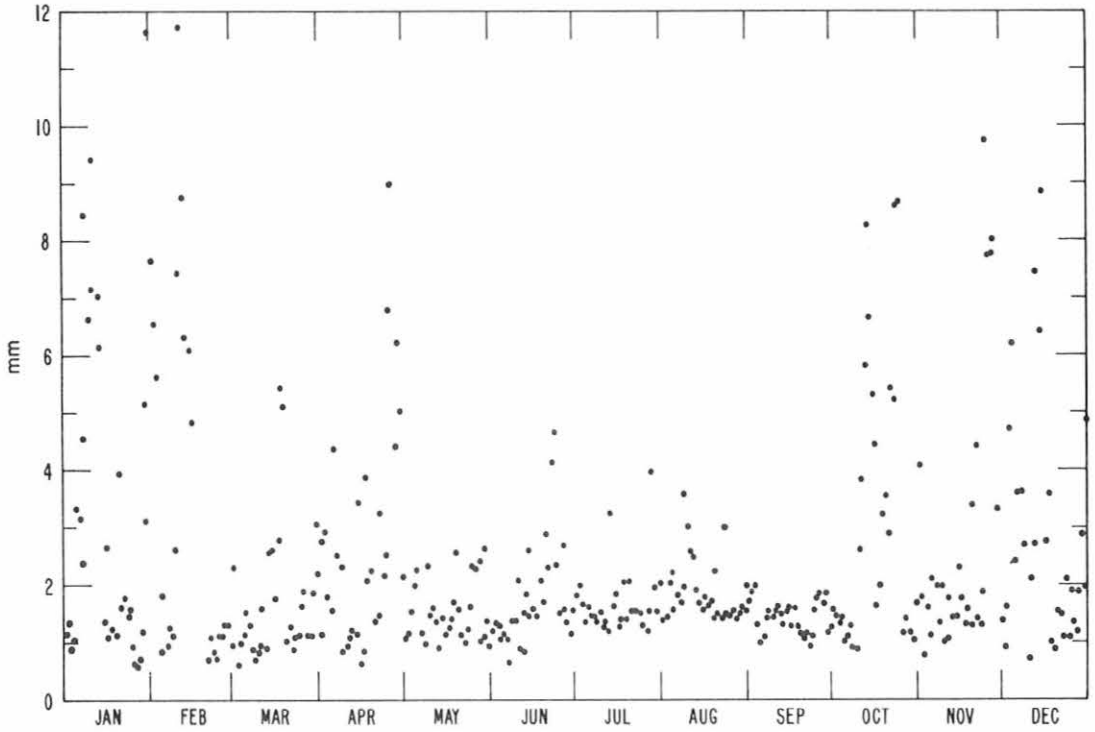


Figure 44. Total precipitable water above Mauna Loa Observatory in 1975. Values were computed from NWS Hilo rawinsonde observations, twice daily, 55 km from the observatory. Daily as well as seasonal variations are evident. Large excursions correspond to synoptic storms and are prevalent during the winter half of the year.

year. Note also that the driest days occur during the winter half of the year when only $\simeq$ 0.6 mm is observed above the observatory. These are also the better optical viewing days during the year.

The plot of cutoff tradewind temperature inversions as determined from the Hilo soundings is shown in Figure 45. A cutoff tradewind temperature inversion is defined as one in which the mixing ratio drops from about 6 to 10 g kg^{-1} to $\leq$ 2.0 g/kg across the inversion layer. Such inversions usually separate a moist sub-inversion layer from a drier upper tropospheric air mass and inhibit extensive vertical mixing. These inversions generally form below the elevation of the observatory and act as a barrier to the upward transport of more turbid marine air past the observatory. The persistency of occurrence intensifies during the summer half of the year and consequently the inversion is more effective in cutting off moisture from higher levels in the summer.

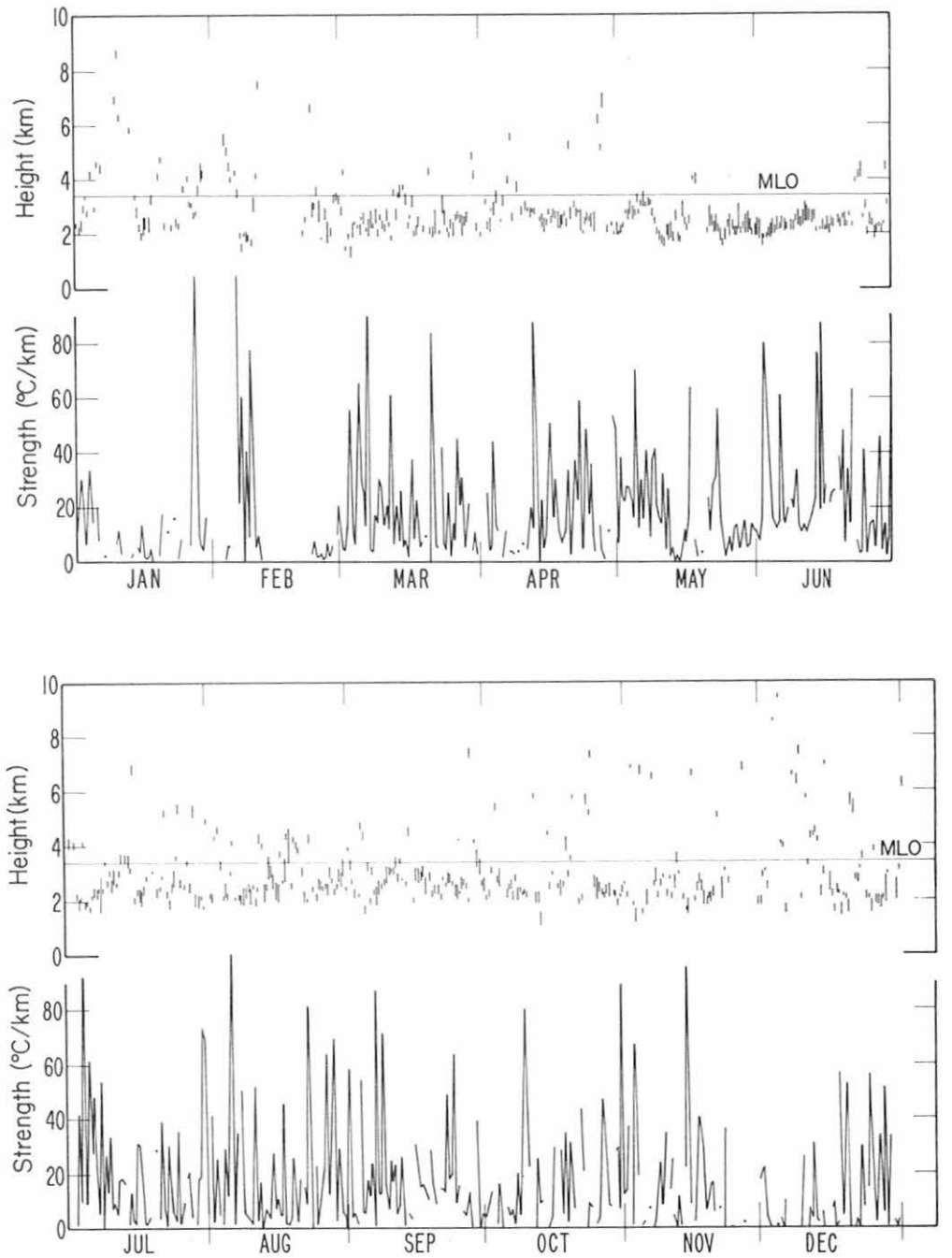


Figure 45. Cutoff tradewind temperature inversions as determined from the NWS Hilo rawinsonde data, twice daily for 1975. The mixing ratio decreases across the inversion from 6 to 10 g/kg to ≤ 2.0 g/kg. Note that the position of the inversion is just below the elevation of the Mauna Loa Observatory where it acts as a barrier to vertical mixing especially during the summer half of the year when the inversion is more persistent and stronger.

Figures 46 and 47 are sample plots of the gradient and jet stream wind layers. In both cases the full year's record shows a significant daily variability in the height and thickness of the layers. The direction of the gradient wind layer is predominantly from the east with a shift to the southeast during the winter. The upper extent of the layer is usually just below the elevation of the observatory. The wind flow is gentle and very consistent throughout the year.

The jet stream is significantly greater in vertical extent having an average vertical thickness of $\simeq$ 5.0 km with a maximum in later winter into spring. This maximum in thickness coincides with the annual maximum in speed. The jet stream is from the west with short periods from the north or northeast. These short periods are the result of upper-level synoptic low-pressure systems and represent periods of downward vertical transport rather than zonal transport from the east.

Summary. Computer processing of NWS Hilo rawinsonde data for 1975 showed the precipitable water content above the observatory to average about 2.6 mm, but to have great daily as well as seasonal varability. The cutoff tradewind inversion acts as a barrier to vertical mixing and vertical moisture advection above the observatory especially during the summer half of the year. It also showed the vertical extent of the trades to be close to the height of the observatory, with a cutoff temperature inversion embedded in the trades at about 0.8 km below.

A deep westerly flow that persists above the observatory intensifies during winter and spring and can extend as low as to the height of the mountain top. This steady upper-level flow provides a constant replenishment and circulation of upper tropospheric air over the observatory for geophysical benchmark monitoring.

4.4.3 Barrow Meteorology

Perched on the poleward extension of the Alaskan north slope, the GMCC observatory at Point Barrow is exposed freely to the wind from all directions. There are no significant topographic barriers within a 300 km radius of the station. The surface wind is, therefore, determined mostly by large-scale synoptic weather features and not by local topography. Between stormy periods when the wind is variable, the local winds are controlled by the outflow from the polar anticyclone which produces a persistent easterly wind at the surface. The most significant local phenomenon is the onset of the stratus cloud deck in the spring. It corresponds with the time the sun is up for most of the day, and the time when extensive leads in the Arctic ocean open along the coast.

In figure 48 the seasonal variation of the wind speed and direction are displayed. Easterly winds are clearly the most prevalent in all months of the year. When directions north through southeast are included, the frequency of occurrence for 1975 was 59%. The secondary maximum in the wind direction distribution is from the west. This could be interpreted as a diurnal occurrence were it not that the prevailing wind direction is easterly for all hours of the day. Westerly winds were most commonly observed in the

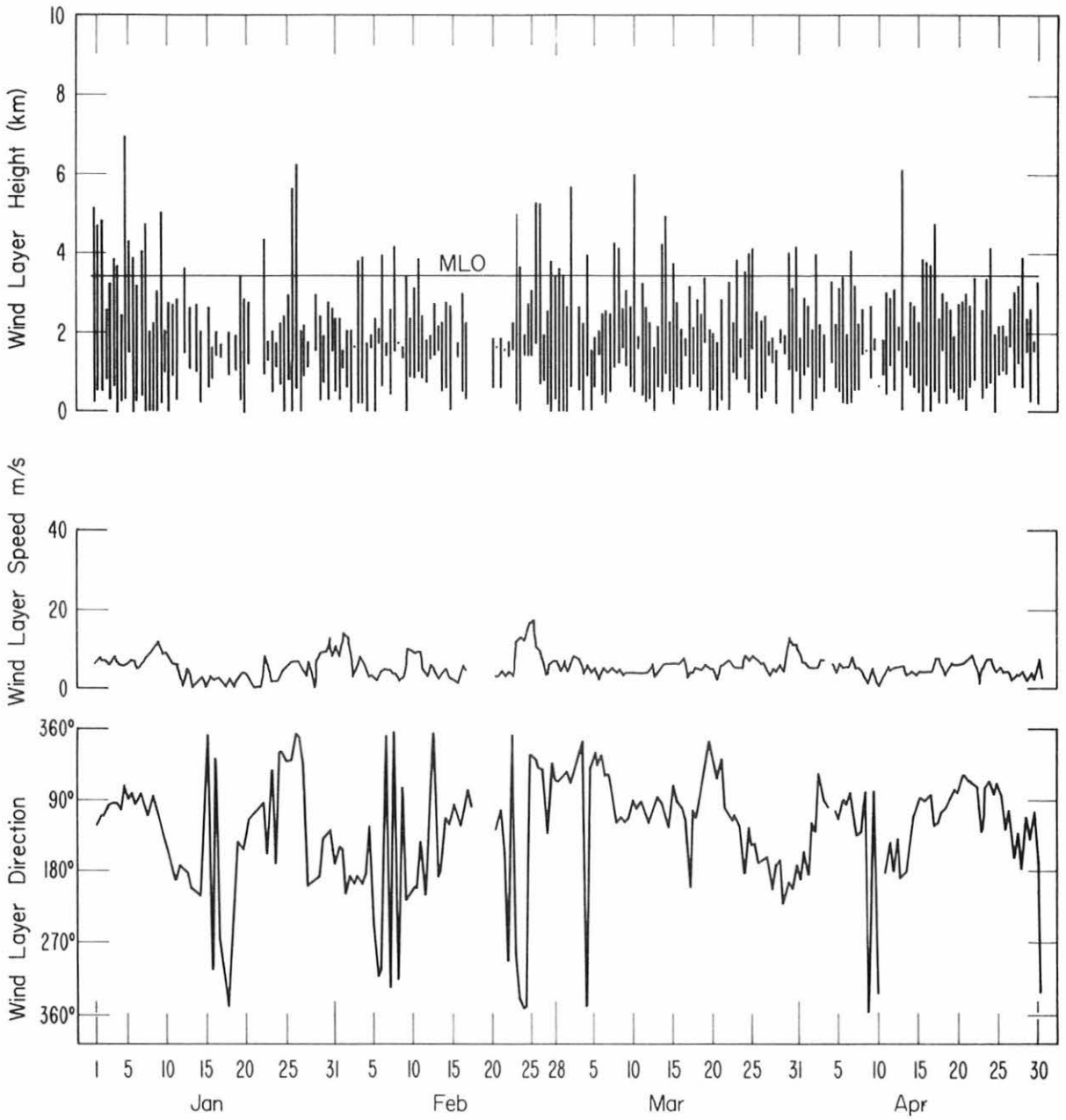


Figure 46. The gradient wind layer (850 mb) as plotted from NWS Hilo 1975 rawinsonde data. The vertical bars show the height and thickness of the layer. Wind speed and direction are the vector sums of the whole layer. Note that the upper extent of the layer is just below the elevation of the Mauna Loa Observatory and represents the tradewind flow over the islands.

summer and winter months. The seasonal variations in wind speed are not pronounced though the speeds seem to be a little higher in winter months. The seasonal variation as a function of wind direction is more pronounced showing a maximum corresponding to the most prevalent wind directions. Calm conditions were reported an average of 1.1% of the time in each month. The average wind speed for the year at Barrow was 6.5 ms^{-1}. The maximum speed was observed on February 7 at 14.3 ms^{-1}.

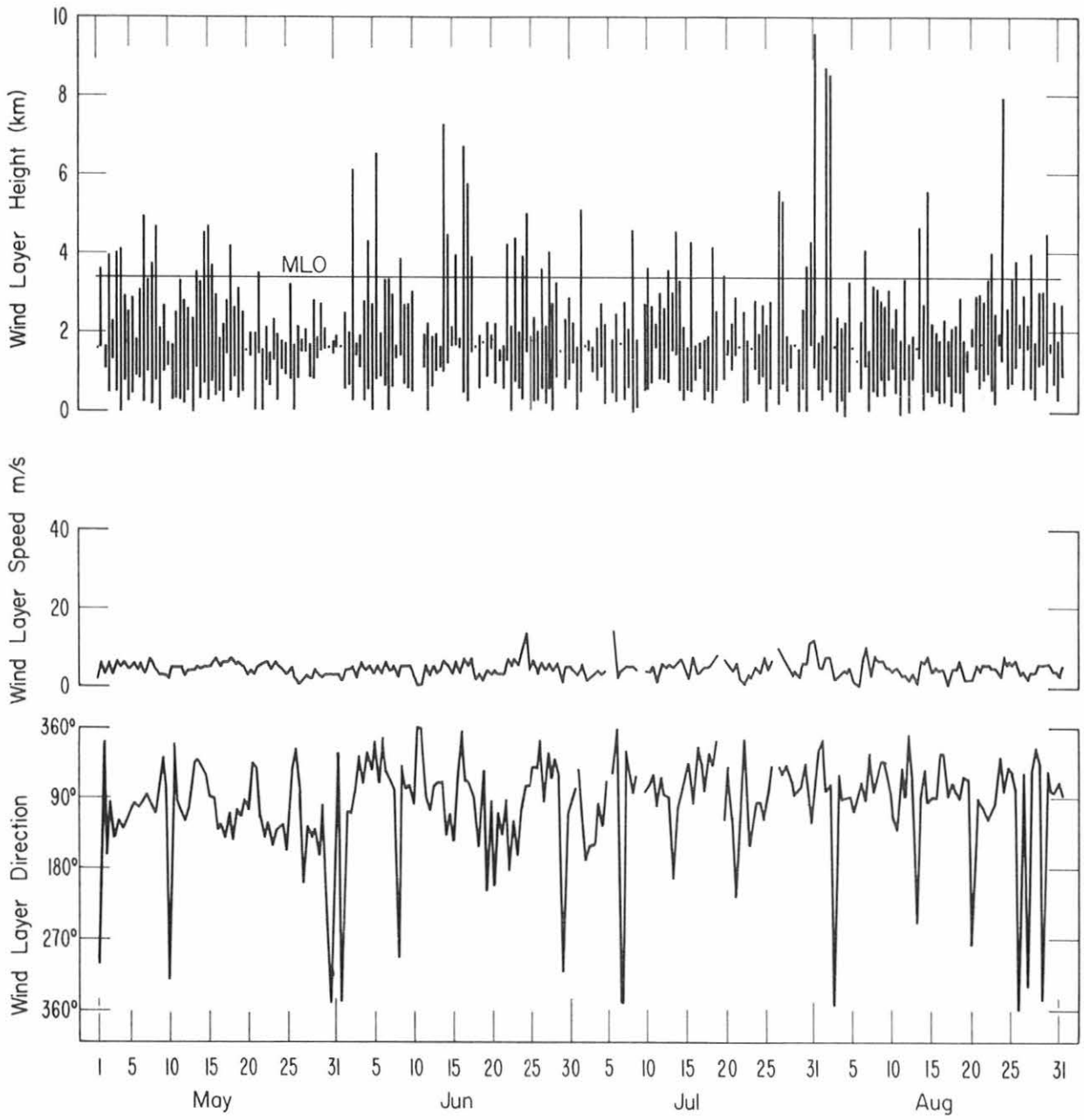


Figure 46. Continued.

In 1975 the National Weather Service station in Barrow reported a minimum temperature of -47°C on January 3. The maximum reading was 18°C on July 7. The average temperature for the year was -14.6°C, a departure of 2.0°C from normal. These values are computed from the NOAA, Environmental Data Service, Local Climatological Data report for the airport station at Barrow, Alaska. These temperature statistics are probably more representative of the village of Barrow and thus generally warmer than at the GMCC observatory, located approximately 7 km to the northeast.

Generally, after the Arctic ice pack breaks away, and large leads open in the ice, the stratus deck moves over Point Barrow to remain as a persistent feature of summer and fall. The stratus is usually established by the

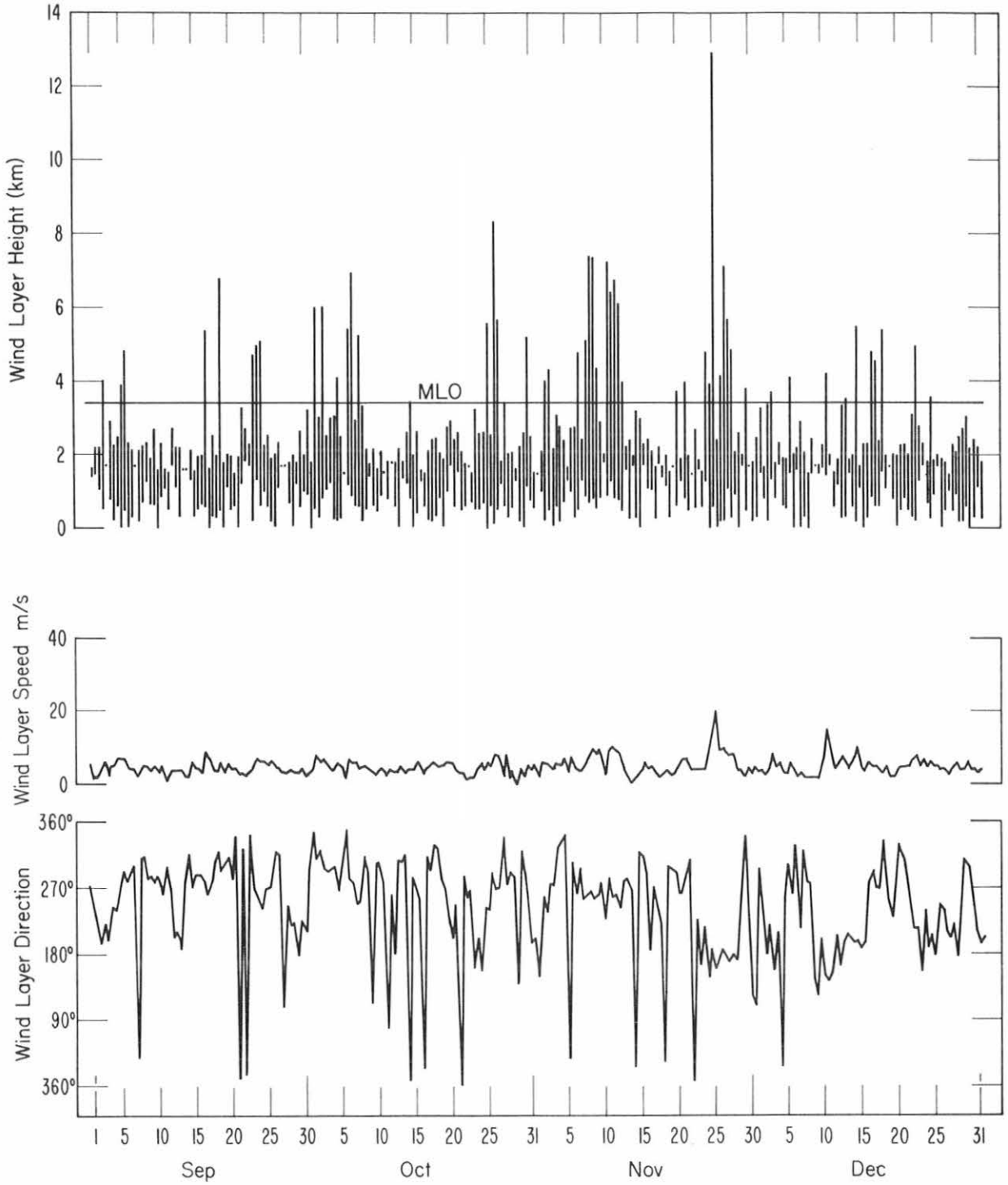


Figure 46. Continued.

middle of May. The average monthly cloud cover, midnight-to-midnight reported for the Barrow airport station, for January through April and November through December 1975, is 4.5/10. For May through November the average monthly cloud cover was 8.4/10. Typically, in this 6-month cloud period only 16 clear (0/10 to 2/10 cloud cover) days can be expected. With the stratus present the ceiling ranges from 0.2 to 0.5 km, in the absence of precipitation.

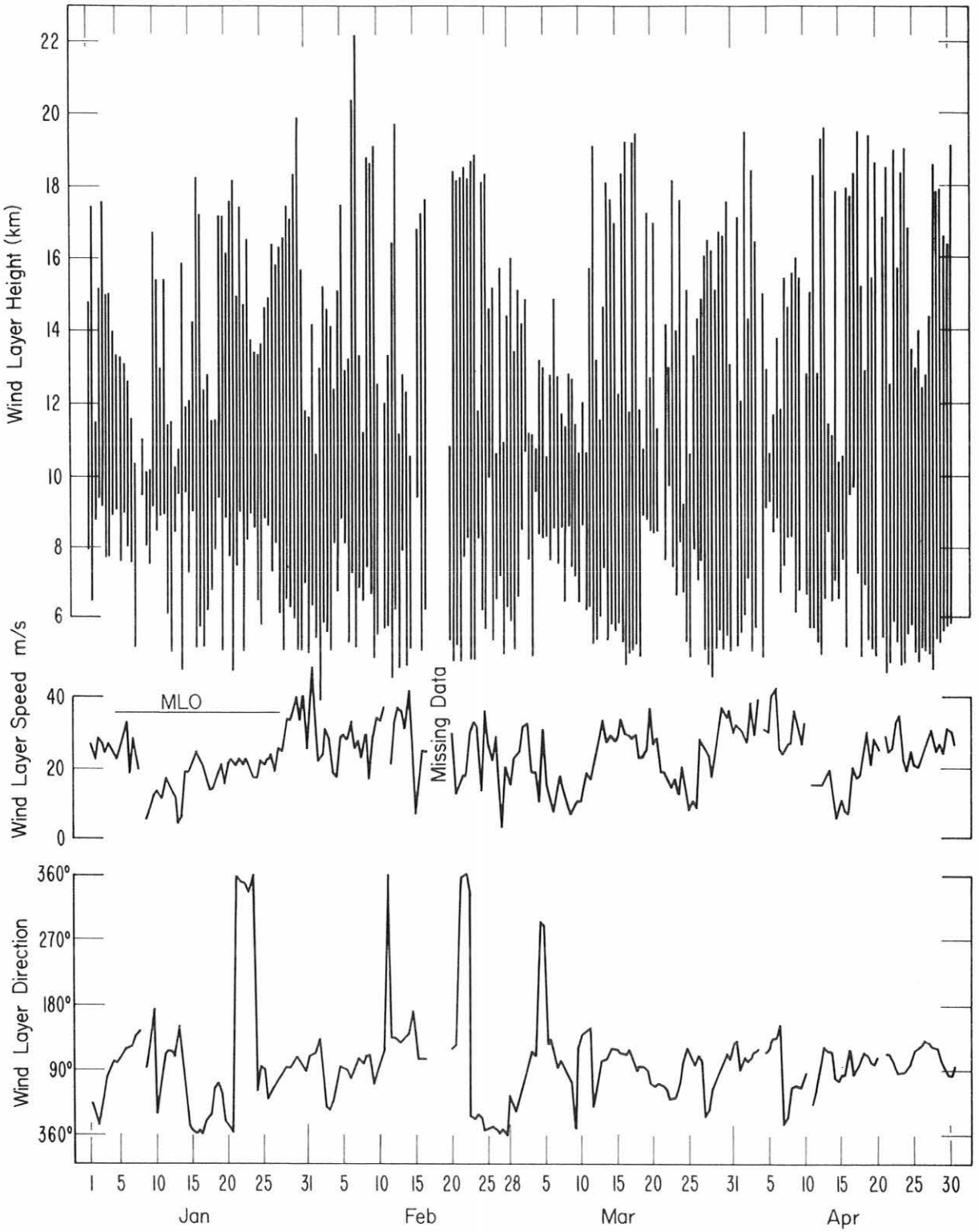


Figure 47. The jet stream wind layer (250 mb) as plotted from NWS Hilo 1975 rawinsonde data. The vertical bars shown the height and thickness of the layer. Wind speed and direction are the vector sums of the whole layer. The jet stream layer intensifies in winter and spring and its downward extent can reach to the height of the top of the mountain.

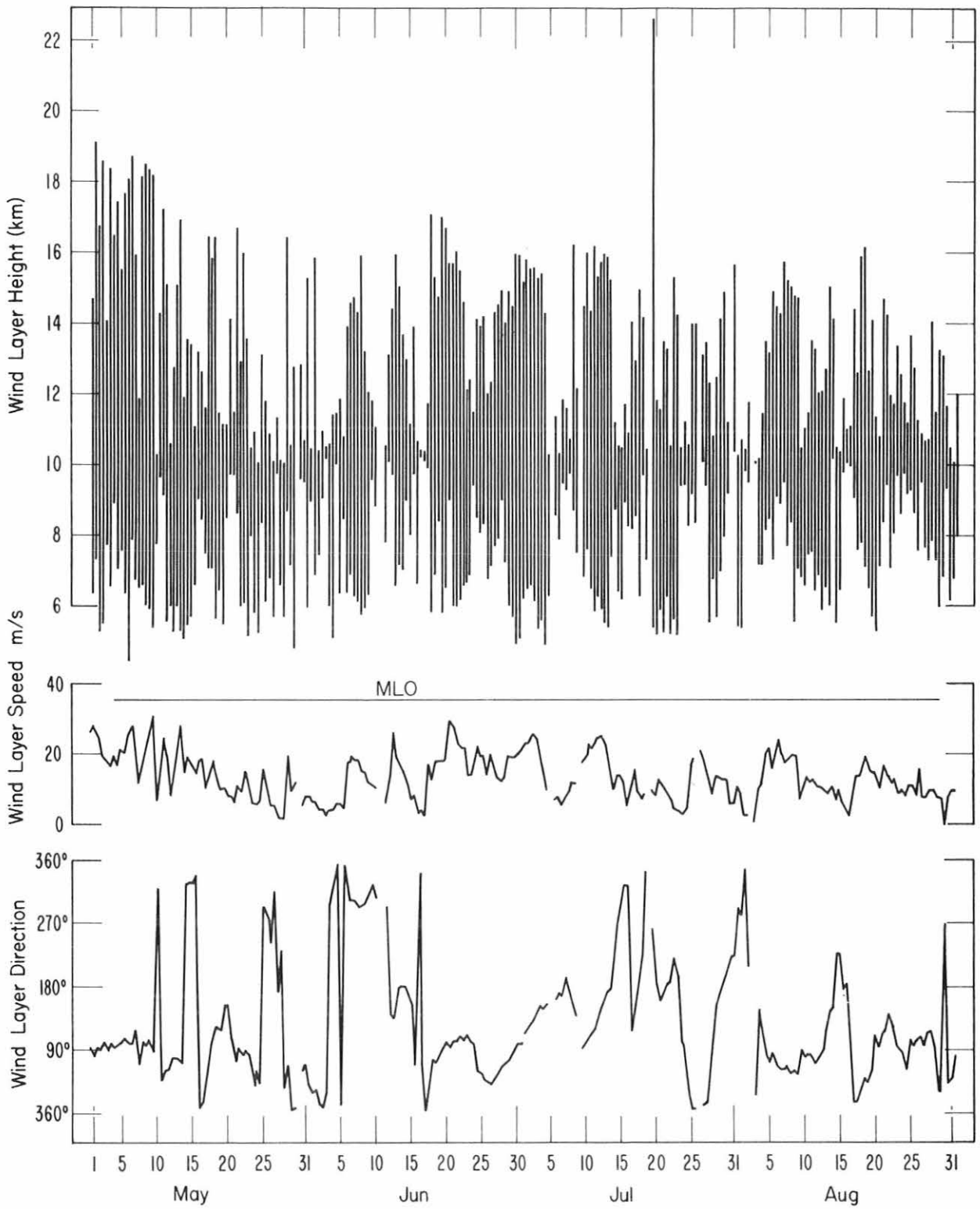


Figure 47. Continued.

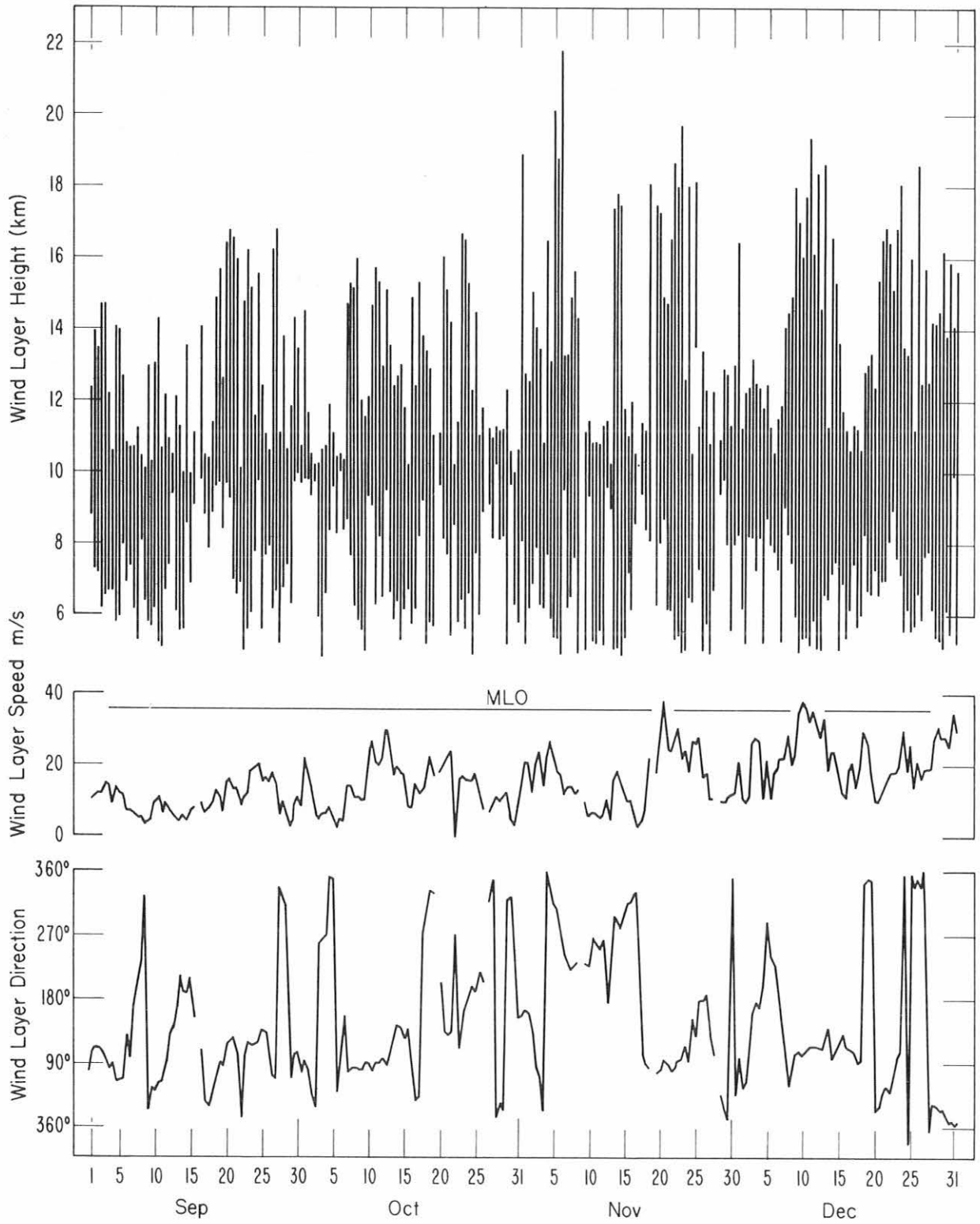


Figure 47. Continued.

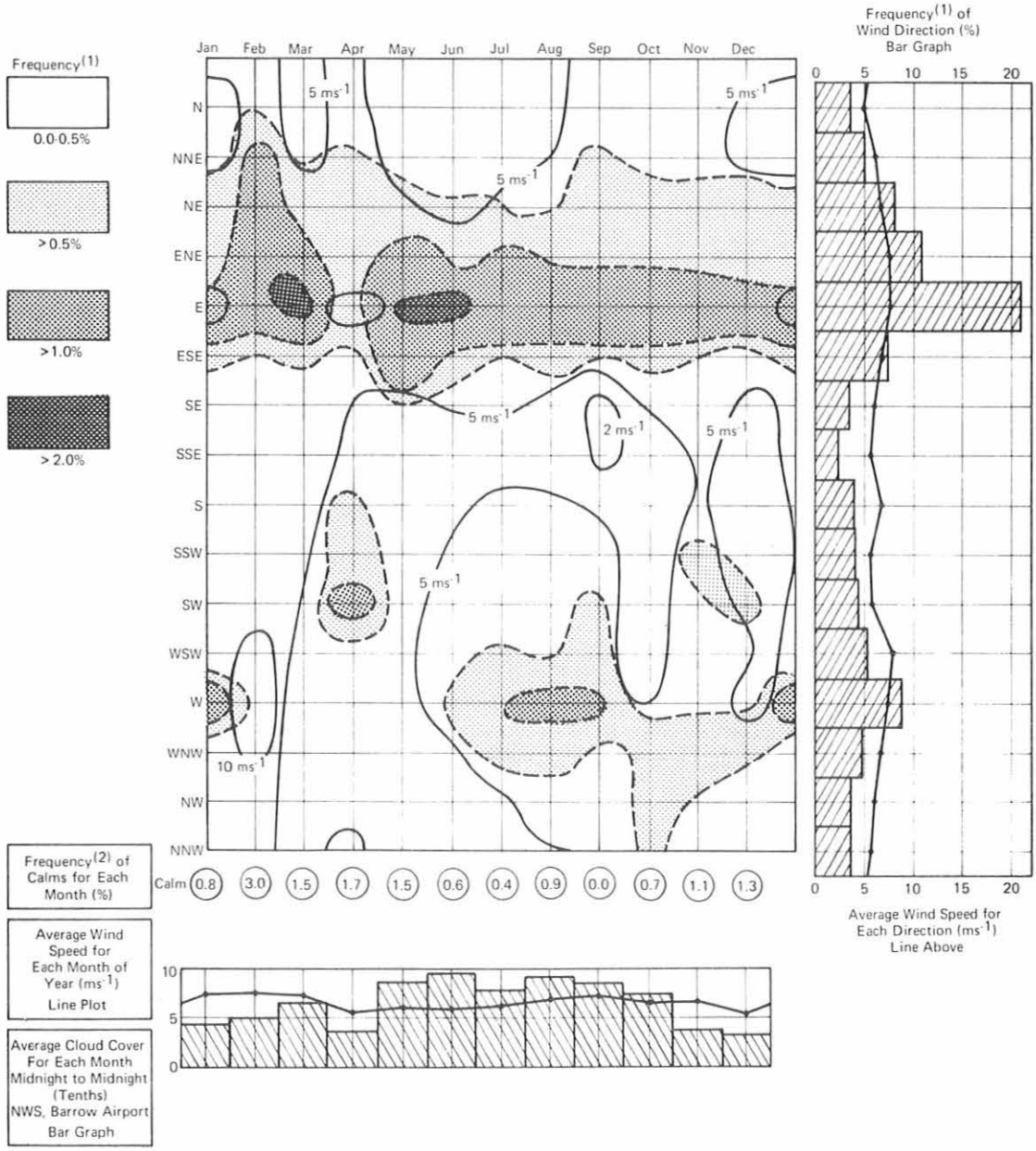


Figure 48. Surface wind and cloud data for GMCC Station, Barrow, Alaska, 1975. (See legend, fig. 50.)

4.4.4 Samoa Meteorology

Figure 49 depicts the monthly variation of wind direction and speed for Cape Matatula for 1975. The prevailing winds are east-southeast in every month of the year. They are especially persistent in the Southern Hemisphere winter months. In the austral summer months of December and January, the Intertropical Convergence Zone (ITCZ) moves further south bringing stormy conditions and northerly winds. The pronounced absence of winds from the

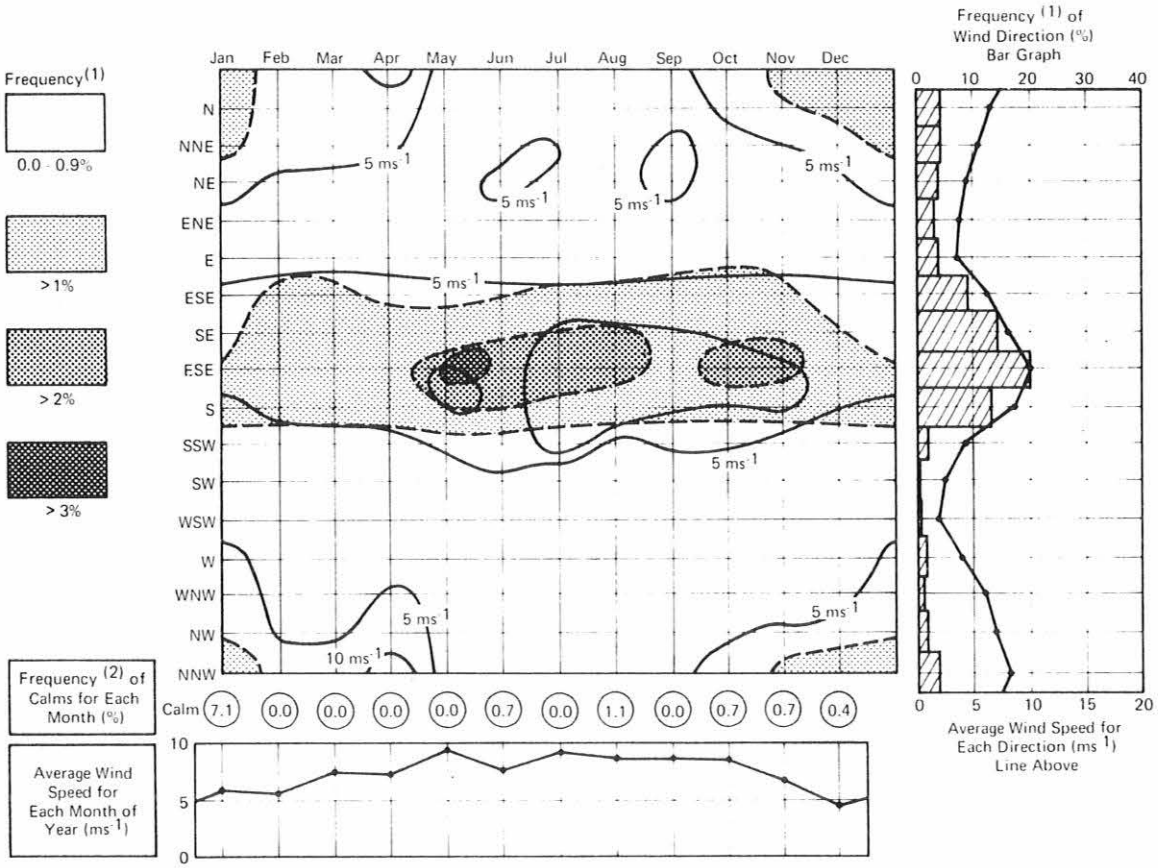


Figure 49. Surface wind data for Cape Matatula, American Samoa, 1975. (See legend, fig. 50.)

southwest is probably caused, in part, by the topography of the cape in the vicinity of the anemometer. Calm conditions were reported an average of 0.9 percent of each month for the year. The average wind speed for the year was 7.5 ms^{-1}. The marginal distribution also shows a pronounced seasonal variation with the minimum speeds in December and January and maximums in May and July. The distribution of wind speed as a function of direction is also well defined with the maximum of 10 ms^{-1} corresponding to the prevailing wind direction, SSE. The maximum hourly average wind speed measured at Cape Matatula in 1975 was 21 ms^{-1} on May 19.

4.4.5 South Pole Meteorology

Throughout most of the year persistent radiation inversions control the local meteorological conditions at the South Pole. Except for brief stormy periods in the spring this strong inversion serves to separate surface winds from conditions aloft. The station sits on the Amundsen-Scott plateau about 2800 m above sea level. This relatively flat plateau, with little relief within a 100-km radius of the station, is in the larger scale depression near

the western edge of the main high ridge of East Antarctica. Surface winds are therefore controlled by the large-scale plateau. The direction of the persistent katabatic wind is easterly.

All weather measurements for 1975 were made at the recently-completed Amundsen-Scott station. The instrumentation is located approximately 100 m grid-northeast of the station. (Direction grid-north is defined as lying along the Greenwich meridian). The anemometer is mounted 10 m, the thermometer 1.5 m, above the snow surface.

Figure 50 is a summary of wind and temperature conditions for 1975. The almost complete absence of winds from the west is the single most striking feature. The dominant wind direction is easterly; for 89% of the time the wind is between north and east inclusive. The strongest wind speed, about 7.7 ms^{-1}, is associated with northerly winds. The average wind speed for the year is 5.0 ms^{-1}. The maximum speed for one hour reported during 1975 was 19.6 ms^{-1}, from grid-north on June 19. The wind was reported as calm only 0.3% of the hours during the year.

4.4.6 GMCC Trajectory Program

The GMCC (air parcel) trajectory program was continued during 1975 with the main emphasis on conversion of the computer system from the CDC 6600 to the IBM 360-195 computer. The data base for the analyzed winds was expanded to the NMC 65 x 65 Northern Hemisphere square grid from the earlier 1977 point grid. Three classes of programs have been developed for the various monitoring stations. These include analyzed wind only from the NMC grid, observed wind only from the global upper air station network, and analyzed-observed wind combined, each of which can be tailored easily to the requirements of the individual stations. This year backward trajectories were computed at various height levels for Adrigole (Ireland), 10-day, analyzed-observed; Ithaca (NY), 5-day, observed only; and Mauna Loa (Hawaii), 10-day, analyzed only. Figure 51 shows the periods for which trajectories have been completed, for these and other stations of interest to the GMCC program. The objective for the coming year is to complete trajectory calculations at all listed stations except for cases where data are missing (at present, analyzed winds for December 1974), as well as maintaining a current (probably 2 to 3 month lag in real time) record for each station. Computer programs including construction of the data base for Samoa and the South Pole may not be initiated until the latter part of 1976.

4.5 Solar Radiation Measurements

4.5.1 Introduction

The GMCC solar radiation program is involved with or owns over 200 radiation sensors that collect data at a rate of about 9,700,000 data points per year. Table 13 summarizes the overall number and location of the instruments

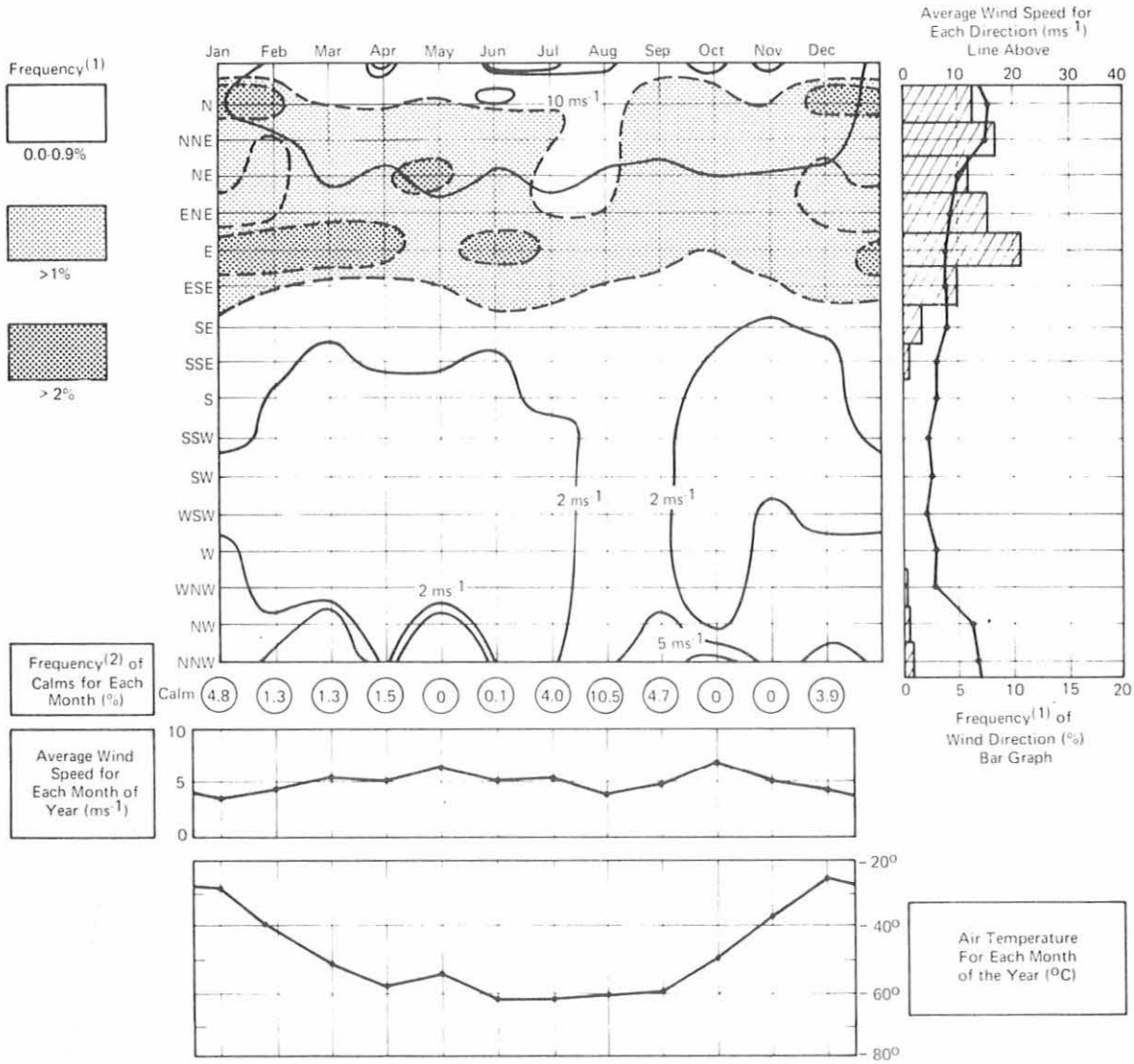


Figure 50. Surface weather data for Amundsen-Scott station, South Pole, 1975.

$$Frequency^{(1)}(\%) = \frac{Number\ of\ occurrences\ of\ the\ event}{\underline{All}\ observations\ during\ year} \times 100$$

$$Frequency^{(2)}(\%) = \frac{Number\ of\ occurrences\ of\ the\ event}{Observations\ for\ \underline{given\ month}\ during\ year} \times 100$$

by type. Detailed calibration histories and locations of the instruments will be published in a NOAA Technical Memorandum sometime during 1976. Since the multichannel pyrheliometers have 15 sensors, the water vapor meters have 2 data channels, and the sunphotometers have 2 data channels, there are 179 data channels represented in the table. These together with the cooperative measurements total over 200 data channels.

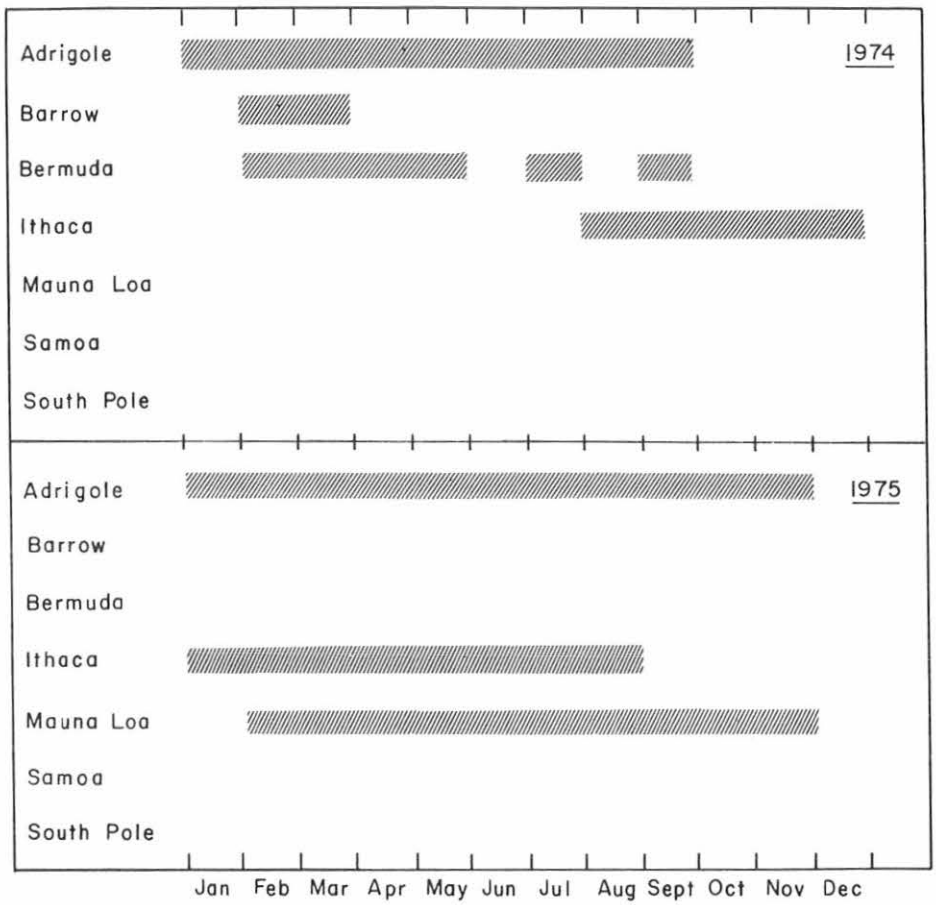


Figure 51. Completed GMCC trajectory programs.

4.5.2 Sample Data Outputs

The following is a brief description of major efforts undertaken in the processing and analysis of the data. Because of the large body of data obtained in 1975, not all data have been processed.

HOURLY AND DAILY INTEGRAL COMPUTATIONS, ALL CHANNELS

Hourly integrals in true solar time were calculated for all the ICDAS data from Mauna Loa for days 189 through 336, 1975, for each instrument channel. Portions of the data from Barrow and from South Pole have been examined in a similar manner.

Day 262 for MLO is illustrated in Table 14 and is taken as a random sample. This was a clear day and the outputs of 16 channels are given and identified below the main table. Certain portions of the data have lines

Table 13. Solar Radiation Instrument Summary

Type	At Field Stations	In Boulder	Total	Acquired in 1975
Pyranometers	26	23	49	11
Multichannel Pyrheliometers	2	3	5	0
Pyrheliometers	3	13	16	12
Water Vapor Meters	1	5	6	5
Sunphotometers	3	7	10	4
Standard Pyrheliometers	0	7	7	0

drawn through them indicating that the data are invalid for instrumental reasons. For example, the pyranometer with the shade disc on channel 17 has invalid data for hours 05 through 08 because of tracking errors on the disc. Channels 22, 23, 26, 27, and 28, and probably 29 and 30, are invalid because of tracking errors of the multichannel radiometer. These tracking errors can be recognized only by comparison of channel 22 and 23 data with the normal incidence pyrheliometer (which is on a separate tracker) data recorded on channel 24. Such loss of data is quite common and data for a better-than-average day are presented here. Other data were lost from intermittent noise or spikes in the signals, tape changes, large amplifier offsets, other tracking errors, lidar operation, or ICDAS down time. Units are in langleys/day except for channels 24 and 25 (the water vapor meter (Foster-Foskett type) channels).

A few other features are also of interest. For example, the daily integral for the bulb type pyranometer 1825 exceeds that for the model 2 pyranometer 12616F3 by 2.8%. The ratio of outputs of the two instruments is, furthermore, not constant during the day, probably indicating differences in cosine response and temperature response. The OG1 pyranometer and the quartz pyranometer output ratios generally vary between 0.70 and 0.75; the RG8 and quartz pyranometer output ratios vary between 0.50 and 0.55. These variations approximate theoretical values, indicating uncertainties of no more than several percent in the instrument calibrations. The same comment applies to the good data from the multichannel radiometer.

COMPARISON OF EXTRATERRESTRIAL AND MEASURED SOLAR INSOLATION

Table 15 illustrates results for pyranometer 12616F3 for a period of eleven days, including day 262 illustrated above. In addition to hourly and daily integrals, information is provided on the fraction of extraterrestrial radiation received. The values are reasonable as may be seen by looking at hours 11 and 12 about true solar noon. On a clear day the predicated percent of transmission is 86.6% according to theoretical values and the maximum

Table 14. Sample Print-out of Hourly and Daily Integrals For One Station For One Day

HOURLY INTEGRALS - SOLAR RADIATION AT MLO(TST) DATE 262 1975 IN LY/HR AND LY/DAY

CALIBRATIONS - 16 125.930 17 143.840 18 136.000 19 130.400 20 5.240 21 155.760 22 153.610 23 338.640

CALIBRATIONS - 24 1.000 25 1.000 26 137.170 27 162.070 28 142.650 29 27.027 30 72.464 31 287.092

CAL. UNITS - MW/CM2/VOLT

CH/HR	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	DAILY
16	.1	10.8	33.0	54.6	73.3	86.1	92.2	91.8	84.3	70.7	52.1	30.3	8.3	-.2	-.1	687.4
17	~~-.0~~	~~10.5~~	~~32.2~~	~~54.9~~	2.6	2.9	3.3	3.5	3.7	3.5	3.2	2.6	1.3	-.3	-.4	~~84.3~~
18	-.1	8.4	25.3	41.0	55.3	64.8	69.2	68.8	63.1	52.9	38.8	22.2	5.5	-.3	-.3	514.5
19	-.3	6.0	18.4	30.2	40.1	47.0	50.0	49.8	45.8	38.6	28.3	16.3	3.9	-.5	-.4	373.2
20	.0	.3	1.1	2.0	2.9	3.5	3.8	3.9	3.6	2.9	2.0	1.1	.3	-.0	-.0	27.4
21	2.8	58.9	80.2	87.6	91.4	~~92.8~~	~~88.5~~	~~84.3~~	~~82.2~~	~~82.8~~	~~81.3~~	~~75.7~~	51.4	.9	.5	~~859.7~~
22	2.8	59.3	80.8	88.1	91.9	~~92.8~~	~~87.5~~	~~83.8~~	~~81.8~~	~~81.2~~	~~81.8~~	~~76.8~~	52.0	1.0	.6	~~858.1~~
23	2.7	59.2	80.7	88.2	91.9	93.3	93.3	92.9	91.6	89.5	85.4	77.0	51.6	.7	.4	998.3
24	1.3	18.6	18.8	21.2	22.3	22.3	22.3	22.3	22.3	22.1	21.8	21.4	19.6	.3	-.0	256.4
25	.6	15.6	17.6	19.6	20.6	20.6	20.4	20.4	20.1	19.8	19.2	18.1	13.5	.0	-.0	226.1
26	2.6	55.8	74.3	80.0	83.0	~~83.6~~	~~82.2~~	~~79.7~~	~~78.8~~	~~77.7~~	~~76.4~~	~~70.9~~	48.8	.7	.4	~~804.1~~
27	2.4	49.3	61.8	65.7	67.7	~~67.5~~	~~64.2~~	~~60.8~~	~~59.8~~	~~59.9~~	~~60.1~~	~~58.1~~	43.5	.6	.2	~~720.3~~
28	2.2	37.8	45.0	47.0	48.2	~~48.1~~	~~45.8~~	~~43.4~~	~~42.4~~	~~42.7~~	~~43.2~~	~~42.2~~	34.0	.8	.5	~~523.2~~
29	.2	.2	.4	.5	.6	.6	.6	.6	.6	.6	.5	.4	.2	.2	.2	6.4
30	.8	9.0	10.0	10.7	11.2	11.3	10.9	10.6	10.2	9.9	9.6	9.0	7.3	.4	.3	121.2
31	-.0	11.4	32.7	54.9	72.9	86.6	96.1	97.0	87.5	72.7	53.7	31.4	9.6	.1	-.1	706.4

CHN.	SERIAL	TYPE	CAL. FOUND ON		COMMENT
16	12616	GQ	.07941	83173	
17	10151	GGG22	.06952	112469	SHADED BY DISK
18	10152	GOG1	.07353	112469	
19	10153	GRG8	.07669	112469	
20	10232	GUV	1.90800	121569	
21	475812	NQ1	.06350	11074	
22	475813	NQ2	.06490	11074	
23	2119	NIP	.02953	60970	
24	-0	H2O	1.00000	-0	
25	-0	H2O	1.00000	-0	
26	4758	NGG22	.07980	11074	
27	4758	NOG1	.06170	82474	BOULDER CAL. ADOPTED
28	4758	NRG8	.07610	11074	
29	4758	N1	.37000	11074	
30	4758	N8	.13800	11074	
31	1825	BULB	.03483	91662	NWS CAL.

Table 15. Sample Results for One Pyranometer

HOURLY INTEGRALS, GLOBAL RADIATION, AND PERCENT OF EXTRATERRESTRIAL AT MLO(TST) IN LY/HR AND LY/DAY

CALIBRATION - 16 125.900

CH/HR	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	DAILY
DATE 255 1975																
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	91.4	85.5	72.6	39.6	33.2	12.4	-.0	-.2	334.7
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.58	81.81	80.86	57.09	74.70	73.11	17.42	0.00	
DATE 256 1975																
16	.1	11.2	33.5	54.9	73.0	85.6	91.8	91.4	84.3	71.1	52.7	31.4	9.5	-.4	-.2	690.0
16	8.15	57.88	72.40	77.42	80.25	81.53	81.88	83.12	82.38	80.78	77.43	72.43	56.73	1.64	0.00	
DATE 257 1975																
16	.2	11.3	34.1	55.9	74.4	87.6	94.3	93.8	86.6	73.3	54.8	32.9	10.1	-.0	-.1	709.3
16	20.76	60.31	75.36	80.54	83.39	85.04	85.62	85.44	84.76	83.57	81.11	76.42	62.11	10.74	0.00	
DATE 258 1975																
16	.2	11.5	34.7	56.7	75.3	88.6	95.0	94.5	87.2	73.5	54.9	32.8	10.1	.1	-.0	715.0
16	10.06	62.67	77.10	81.96	84.75	86.24	87.05	86.31	85.60	84.09	81.59	76.65	63.11	4.55	0.00	
DATE 259 1975																
16	.1	11.4	34.6	56.5	75.1	88.1	94.3	94.5	86.0	73.0	54.1	32.0	9.4	-.1	-.1	709.1
16	41.41	61.00	76.58	81.67	84.54	85.90	86.12	86.60	84.85	84.05	81.23	76.08	62.54	24.57	0.00	
DATE 260 1975																
16	.1	11.1	34.0	55.8	74.2	86.8	93.0	93.1	75.3	44.0	43.1	26.1	6.7	.1	-.1	643.3
16	9.58	60.30	75.86	80.94	83.79	84.86	85.16	85.64	74.51	51.18	64.62	61.55	46.82	2.46	0.00	
DATE 261 1975																
16	.2	10.8	33.2	54.8	73.2	86.4	92.7	92.0	84.3	70.9	52.3	30.5	8.4	-.2	-.1	689.4
16	7.12	57.79	73.77	79.36	82.59	84.50	85.11	84.84	83.69	81.89	79.37	73.89	56.66	.04	0.00	
DATE 262 1975																
16	.1	10.8	33.0	54.6	73.3	86.1	92.2	91.8	84.3	70.7	52.1	30.3	8.3	-.2	-.1	687.4
16	10.57	58.69	73.81	79.41	82.95	84.47	84.86	84.88	84.09	82.48	79.75	74.09	57.52	.00	0.00	
DATE 263 1975																
16	.1	10.8	33.2	54.8	73.2	86.1	92.2	94.3	61.1	56.5	53.5	29.8	7.8	-.4	-.3	652.9
16	6.37	59.38	74.66	80.05	83.21	84.76	85.08	87.50	61.61	65.70	82.02	73.41	51.64	.00	0.00	
DATE 264 1975																
16	.1	10.7	33.0	54.5	72.8	85.3	91.2	85.0	63.3	58.8	41.7	27.2	7.6	-.1	-.1	631.0
16	11.61	58.23	73.90	79.47	82.74	84.06	84.36	79.16	63.83	69.51	65.18	68.34	58.43	.00	0.00	
DATE 265 1975																
16	.1	10.4	32.4	53.6	71.7	84.4	90.6	89.9	84.3	0.0	0.0	0.0	0.0	0.0	0.0	517.3
16	7.24	57.27	73.00	78.48	81.76	83.46	84.04	83.87	83.52	69.51	65.18	68.34	58.43	.00	0.00	

value here is 87.5% with a minimum of 79.16%, perhaps due to clouds during part of the hour. Average of all the observations is 84.72%, and for those values exceeding 83.87% the average is 85.44%. The agreement between observation and theory is satisfactory indicating there is no serious problem with the instrument. An analysis of this type has been performed at Mauna Loa for all pyranometer data obtained with instrument 12616F3 between days 189 and 336, 1975.

IRRADIANCE VALUES AT SELECTED AIR MASS VALUES

Mauna Loa irradiance values at selected air mass values have been examined since the beginning of the solar radiation program. Irradiance values at 64 selected air mass values for each day through April 1974 are on tape. Recently, with the installation of the ICDAS at Mauna Loa and the installation of the CDC6600 computer at Boulder, new programs have been written to study these data.

Table 16 gives a sample program output showing morning, true solar noon (TSN), and afternoon irradiance values for the first 11 channels of instruments identified in Table 14. The ratios of the outputs of the instruments to those of other selected instruments are also given. For example, the ratio 18/16 is the ratio of OG1 pyranometer and the quartz pyranometer outputs; 23/21 is the ratio of the NIP output to the output of the first quartz channel of the multichannel pyrheliometer which, if the measuring systems were perfect, would equal one at all times. The tracking error for the multichannel pyrheliometer mentioned in the above description of the hourly integrals is again evident in this table about true solar noon and later. Irradiances are selected at given air mass values because in the long term the data will be selected from the same homogeneous population.

IRRADIANCE VALUES AT SELECTED AIR MASS VALUES, CORRECTED TO ONE ASTRONOMICAL UNIT

Table 17 lists some typical corrected values for day 262, 1975, at MLO. Such adjustments (a.u.) are necessary to compare corresponding values from day to day and from year to year, and to theoretical values which are generally tabulated at one a.u. Air mass values 1.34, 2.01, 2.69, and 3.36 were selected following the procedure of Ellis and Pueschel (1971), so that this tradition at Mauna Loa would not be broken.

It is necessary to obtain hard copies of irradiance values before slope and turbidity analyses can proceed. This procedure allows the validity of the data to be checked which cannot be done by computer. Invalid data may arise from tracking errors which the computer cannot distinguish from high turbidity values. The cost of the analysis procedures is increased by such validation requirements.

PYRANOMETER OUTPUT PLOTS

Figure 52 reproduces plots of the pyranometer irradiances (channels 16 through 20) on days 262 and 263 at Mauna Loa. Such plots are valuable for identifying instrument problems. For example at about 0830 on day 262 there

Table 16. Sample Irradiance Values For One Day at One Station

IRRADIANCE VALUES AT SELECTED AIR MASSES
MLO 1975 DOY=262 TRUE SOLAR NOON=2216.

CH/AM	8	7	6	5	4	3	2	1	TSN
SLE*	12.2	10.6	9.1	7.6	6.1	4.6	3.0	1.5	
16	68.217	106.963	129.473	119.356	236.644	375.330	769.355	1545.570	-1727.357
	-28.968	-39.377	-45.184	-63.170	-78.928	-125.462	-241.032	-404.635	
17	67.267	105.485	126.937	116.659	230.240	358.277	741.737	58.121	-62.613
	-7.219	-9.121	-9.594	-11.117	-11.596	-15.600	-21.864	-21.966	
17/16	.986	.986	.980	.973	.973	.955	.964	.038	.036
	.249	.232	.212	.176	.147	.124	.091	.054	
18	52.708	82.675	100.163	92.980	183.402	290.822	591.000	1154.803	-1295.515
	-16.778	-23.599	-28.463	-42.036	-54.609	-89.137	-175.837	-302.127	
18/16	.773	.773	.774	.775	.775	.775	.768	.747	.750
	.579	.599	.630	.665	.692	.710	.730	.747	
19	48.557	77.313	95.413	89.170	175.175	276.847	573.143	1126.025	-1243.473
	-15.534	-22.443	-26.293	-33.751	-52.619	-86.778	-171.708	-292.894	
19/16	.712	.723	.737	.743	.740	.743	.745	.729	.720
	.536	.570	.582	.629	.667	.692	.712	.724	
20	2.192	3.356	3.961	3.650	7.284	11.866	26.039	56.593	-72.491
	-.978	-1.269	-1.436	-1.991	-2.526	-4.154	-8.575	-16.335	
20/16	.032	.031	.031	.030	.031	.032	.034	.038	.042
	.034	.033	.032	.032	.032	.033	.036	.040	
21	751.067	1034.957	1035.060	822.693	1291.619	1551.347	2193.965	2251.012	-1605.329
	-328.641	-387.576	-375.567	-431.382	-428.150	-522.477	-664.349	-545.495	
22	754.252	1039.360	1039.349	825.201	1298.246	1559.660	2207.010	2259.047	-1579.970
	-331.761	-391.210	-379.027	-435.936	-431.420	-525.072	-666.586	-540.482	
22/21	1.004	1.004	1.004	1.004	1.005	1.005	1.006	1.003	.984
	1.009	1.009	1.009	1.009	1.008	1.006	1.003	.991	
23	746.259	1028.331	1031.100	818.826	1286.073	1548.460	2187.023	2248.448	-1718.828
	-324.669	-383.102	-371.122	-426.502	-424.522	-519.855	-667.925	-575.830	
23/21	.994	.994	.995	.995	.996	.998	.997	.999	1.071
	.999	.999	.988	.992	.992	.995	1.005	1.056	
24	268.397	377.109	394.664	266.163	364.604	422.696	533.335	564.645	-415.750
	-141.465	-158.591	-145.447	-150.372	-143.227	-162.110	-166.896	-144.685	
25	220.317	306.443	293.447	220.381	336.416	383.412	496.684	516.351	-379.259
	-94.264	-119.110	-105.106	-118.334	-112.169	-131.378	-158.846	-129.187	
25/24	.789	.787	.827	.851	.880	.907	.931	.914	.912
	.667	.630	.723	.759	.763	.810	.841	.892	
26	710.519	976.599	977.233	773.709	1210.684	1444.808	2022.419	2034.315	-1491.837
	-310.137	-369.437	-353.078	-405.277	-401.001	-487.567	-616.123	-509.136	
26/21	.946	.943	.943	.941	.937	.931	.922	.903	.929
	.944	.943	.942	.940	.937	.933	.927	.933	
27	666.484	909.494	894.728	688.733	1069.489	1251.891	1711.527	1677.572	-1158.732
	-290.664	-339.748	-323.818	-364.575	-354.310	-419.263	-511.032	-398.990	
27/21	.887	.875	.864	.851	.828	.807	.780	.745	.722
	.892	.877	.862	.844	.828	.802	.770	.731	

Note: Values are in $mWcm^{-2}$. For each channel, the upper values are for morning and the lower values are for afternoon.

is evidence that tracking on the disc shading the GG22 pyranometer was corrected. The plot for day 263 shows that the pyranometer was not shaded at all. The tabulated daily integrals in watts m^{-2} for each channel are shown along the bottom. One langley per day = 0.484468 Wm^{-2}.

LANGLEY PLOT SLOPE AND INTERCEPT VALUES FOR ALL CHANNELS

Langley plots for all the output channels at Mauna Loa were derived for several days. The objective of this program was: 1) To determine values of aerosol optical depth using the reference channel of the water vapor meter. 2) To determine if both the pyranometers and pyrheliometers were calibrated

Table 17. Sample Irradiance Values, Adjusted to 1 a.u., For One Day at One Station

SEE IDENTIFYING LIST OF INSTRUMENTS ON INTEGRAL OUTPUT SHEETS
MLO 1975 DOY=263 TRUE SOLAR NOON=2216.

CH/AM	3.36	2.69	2.01	1.34	1.10	.90	.80	.70	TSN
16	16.785	22.110	31.541	51.532	64.229	81.548	93.019	107.775	108.993
	16.378	22.007	31.371	51.325	67.031	85.838	81.132	111.083	
17	16.120	21.046	30.057	49.495	61.992	78.502	89.619	103.261	104.370
	14.513	19.749	28.746	48.179	63.648	75.740	74.318	106.188	
17/16	.960	.952	.953	.960	.965	.963	.963	.958	.958
	.886	.897	.916	.939	.950	.882	.916	.956	
18	12.995	17.118	24.121	39.485	48.093	61.672	70.193	80.975	81.911
	11.456	15.763	22.843	38.206	50.289	65.068	60.916	83.103	
18/16	.774	.774	.765	.766	.749	.756	.755	.751	.752
	.699	.716	.728	.744	.750	.758	.751	.748	
19	12.416	16.544	23.284	38.140	47.575	59.883	67.853	78.240	79.203
	11.276	15.561	22.570	37.026	48.931	62.683	58.496	79.776	
19/16	.740	.748	.738	.741	.741	.734	.729	.726	.727
	.699	.707	.719	.721	.730	.730	.721	.718	
20	.519	.703	1.047	1.834	2.374	3.135	3.679	4.488	4.607
	.535	.747	1.126	1.973	2.602	3.393	3.372	4.692	
20/16	.031	.032	.033	.036	.037	.038	.040	.042	.042
	.033	.034	.036	.038	.039	.040	.042	.042	
21	78.415	83.116	89.398	95.059	93.827	86.902	74.178	57.015	49.130
	1.244	1.265	1.301	1.359	1.354	2.080	1.601	44.012	
21/21	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
22	79.669	84.723	91.192	97.253	96.076	88.781	76.256	58.993	51.161
	1.429	1.449	1.469	1.546	1.548	2.326	1.832	46.081	
22/21	1.016	1.019	1.020	1.023	1.024	1.022	1.028	1.035	1.041
	1.149	1.146	1.129	1.138	1.143	1.118	1.144	1.047	
23	81.061	86.54.	93.381	101.401	104.702	107.852	108.980	109.948	109.111
	.509	.756	.731	.588	.459	.525	.958	107.046	
23/21	1.034	1.041	1.045	1.067	1.116	1.241	1.469	1.928	2.221
	.419	.598	.539	.433	.339	.252	.599	2.432	
24	26.187	26.131	25.890	25.560	25.262	25.165	24.902	24.727	24.610
	24.924	25.175	25.431	25.778	26.145	23.227	17.499	24.704	
24/25	1.118	1.101	1.083	1.065	1.058	1.050	1.049	1.060	1.073
	1.262	1.242	1.217	1.158	1.168	1.158	1.142	1.106	
25	23.424	23.739	23.895	24.102	23.877	23.970	23.732	23.325	22.925
	19.745	21.298	20.895	22.256	22.303	19.382	15.323	22.339	
25/25	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	1.000	1.000	1.000	1.001	1.000	1.000	1.000	1.000	
26	73.333	77.660	83.164	88.395	88.252	84.289	75.224	60.981	54.075
	1.374	1.449	1.525	1.577	1.617	2.347	1.785	49.334	
26/21	.935	.934	.930	.930	.941	.970	1.014	1.070	1.101
	1.105	1.145	1.172	1.161	1.194	1.128	1.115	1.121	

Note: Values are in $mWcm^{-2}$. For each channel, the upper values are for morning and the lower values are for afternoon.

on the same radiation scale. 3) To determine if the procedure of Ellis and Pueschel (1971) for determining turbidity could be treated in a more general manner. 4) To determine if total precipitable water vapor amounts could be found by using the more general procedure.

Theoretical considerations indicate that all of the above objectives can be met but the present data are too noisy to yield meaningful results. Measured aerosol optical depths are small and often negative because of measurement inaccuracies. Langley plot intercepts obtained with pyranometers are 7% to 10% higher than those obtained with pyrheliometers, indicating that calibration problems are not serious although problems at the 1% to 2% level are not eliminated. The slope uncertainties are greater than those given by

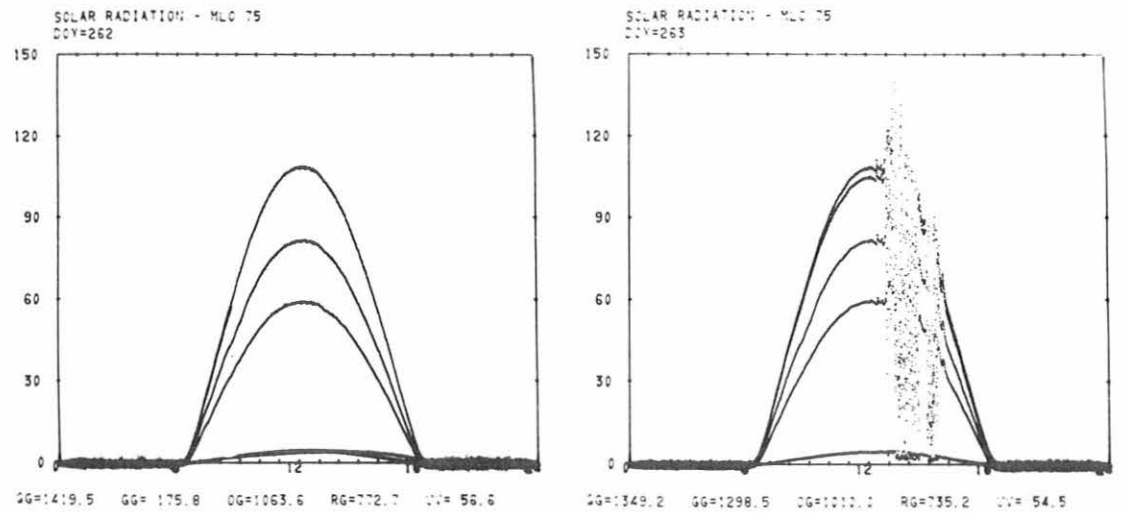


Figure 52. Pyranometer-produced plots of irradiance in $mWcm^{-2}$.

Ellis and Pueschel but more easily interpretable in terms of total optical depth because of higher resolution type measurements. Total precipitable water vapor amounts have uncertainties of at least ±3 mm. This technique of deriving Langley plots will be further investigated and refined during 1976.

ANGSTROM TURBIDITY COEFFICIENTS

Analysis showed that deviations of Angstrom turbidity coefficients from the multichannel radiometer are not possible with the given instrument calibration constants. A similar conclusion was reached recently by G. D. Robinson (1976).

4.5.3 International Pyrheliometric Comparison, Davos, Switzerland

GMCC participated in the International Pyrheliometric Comparison IV as part of the NOAA contingent from October 6 to October 24, 1975. Two GMCC instruments were used: Ångstrom pyrheliometer Å10180 and Eppley-Kendall radiometer 12843. Both instruments were also used in pre-Davos and post-Davos comparisons in Boulder and Å10180 also in the Table Mountain Comparison of 1972.

The ratios of the response of these instruments to instruments representing the Kendall radiometer scale are listed below:

Place/Date	Å10180	EK 12843	Ref. instrument
Table Mtn., Oct., 1972	0.9741	------	PACRAD 2
Boulder, Aug., 1975	0.9726	0.9996	TMI-67502
Davos, Oct., 1975	0.9702	0.9999	TMI-67502
Boulder, Jan., 1976	0.9727	1.0004	TMI-67502

The ratio of TMI-67502 to the reference PACRAD at Davos is 0.9997.

The comparisons indicate both Å10180 and EK 12843 have remained stable during the series of comparisons and serve to tie our instruments to the international standards and meteorological radiation scales.

4.5.4 Water Vapor Meters

In 1973, development of five water vapor meters was started by the High Altitude Observatory, NCAR, at the request of GMCC. The purpose of the water vapor meter measurements will be to provide information on, 1, the daily and seasonal variations in total precipitable water; 2, the correlation between total precipitable water and measurements of direct, diffuse, and global radiation; 3, the correlation between total precipitable water and turbidity; and, in conjunction with pyroelectric turbidity meter observations described elsewhere, the wavelength dependence of the direct radiation, the internal consistency of the measurements, the residual absorption due to dust, and causes of the seasonal and perhaps long-term trends of transmission of the atmosphere and of the solar constant.

4.5.5 Miscellaneous Topics

CALCULATION OF THEORETICAL RADIATION CLIMATOLOGIES FOR ALL GMCC STATIONS

Expected insolation values in $lyday^{-1}$ and Wm^{-2} for each day of the year, for each station and pyranometer, were calculated along with other components of the solar radiation budget, terrestrial radiation budget, and meridional mean climatology. The purpose of these calculations was to check on the performance of the pyranometers and ICDAS so that any obvious errors in the data collection could be easily and quickly corrected.

The calculation techniques are being published elsewhere (Hoyt, 1976). A sample of the output for Boulder is illustrated in Table 18. The columns in the upper half give the following information: 1) the day of the year, 2) the daily total extraterrestrial solar irradiance on a horizontal surface at the top of the atmosphere, 3) the daily total absorption by water vapor, 4) the sum of the daily total absorptions by ozone, carbon dioxide, and oxygen, 5) the daily total dust absorption, 6) the sum of the previous three columns, 7) the daily total direct irradiance, 8) the daily total diffuse irradiance, 9) the daily total global irradiance, and 10) the ratio of the global irradiance to the extraterrestrial irradiance. In the lower half are given 1) the day of the year repeated, 2) the daily total global irradiance for wavelengths greater than 530 nm (λ>530 nm), 3) the daily total absorption by water vapor, 4) the same for λ>695 nm, 5) the daily total normal incidence irradiance, 6) the daily total irradiance absorbed at the Earth's surface from the diffuse component, 7) the direct component, 8) the global radiation, 9) the total daily radiation reflected to space at the top of the atmosphere, and 10) the total daily radiation absorbed in the Earth's atmosphere and at the Earth's surface.

These tables have already proved useful to the solar radiation program by indicating errors in the values of the calibration constants placed in the ICDAS accidently.

Table 18. Sample of Radiation Climatology Data

SOLAR RADIATION RESULTS AT
BOULDER,COLO. INTEGRAL VALUES 2 FOR NC = 7

DAY	INSOLATION OG1	RG2	RG8	NORMAL	ABS. AT SURFACE DIF.	DIFF.	GLOBAL	REFL. TOP	TOTAL ABS.
1.	343.1	280.1	236.8	917.4	210.1	91.4	301.4	236.8	440.8
2.	345.0	281.6	238.1	921.3	211.5	91.5	303.0	238.0	442.3
3.	347.0	283.3	239.6	925.5	213.0	91.7	304.6	239.2	444.1
4.	349.2	285.1	241.3	929.9	214.6	91.8	306.4	240.6	445.9
5.	351.6	287.1	243.0	934.8	216.4	92.0	308.4	241.9	448.0
6.	354.2	289.2	244.8	939.9	218.2	92.2	310.5	243.3	450.3
7.	356.8	291.4	246.7	945.2	220.2	92.5	312.7	244.8	452.7
8.	359.7	293.7	248.8	950.9	222.3	92.7	315.0	246.4	455.3
9.	362.7	296.2	250.9	956.7	224.6	92.9	317.5	248.1	458.0
10.	365.8	298.8	253.2	962.9	226.9	93.2	320.1	249.9	460.8
11.	369.1	301.4	255.6	969.3	229.3	93.4	322.8	251.8	463.8
12.	372.5	304.3	258.0	975.9	231.9	93.7	325.6	253.9	466.9
13.	376.1	307.2	260.6	982.7	234.6	94.0	328.5	256.0	470.1
14.	379.8	310.2	[illegible]	[illegible]7	237.3	[illegible]	[illegible].6	258.2	473.5
15.	383.7	31[illegible]			[illegible]40			260.6	476 [illegible]
16.	387.[illegible]							262.4	
17.	[illegible]								

SOLAR RADIATION RESULTS AT
BOULDER,COLO. INTEGRAL VALUES 2 FOR NC = 7

DAY	EXT. INSOL.	ATMOSPHERIC ABSORPTION H2O	MINOR	DUST	TOTAL	INSOLATION DIRECT	DIFF.	GLOBAL	RATIO
1.	677.6	77.5	56.3	5.5	139.3	347.8	151.3	499.1	.737
2.	680.3	77.4	56.4	5.5	139.4	350.1	151.5	501.6	.737
3.	683.3	77.4	56.5	5.5	139.4	352.6	151.8	504.4	.738
4.	686.5	77.4	56.6	5.5	139.5	355.3	152.0	507.3	.739
5.	689.9	77.4	56.7	5.5	139.6	358.2	152.3	510.6	.740
6.	693.6	77.4	56.9	5.5	139.8	361.3	152.7	514.0	.741
7.	697.5	77.5	57.0	5.5	140.0	364.6	153.1	517.7	.742
8.	701.7	77.5	57.2	5.6	140.3	368.1	153.5	521.6	.743
9.	706.1	77.6	57.3	5.6	140.5	371.8	153.9	525.6	.744
10.	710.8	77.7	57.5	5.6	140.8	375.6	154.3	529.9	.746
11.	715.7	77.8	57.7	5.6	141.0	379.7	154.7	534.4	.747
12.	720.8	77.9	57.8	5.6	141.3	383.9	155.1	539.1	.748
13.	726.1	78.0	58.0	5.6	141.6	388.4	155.6	544.0	.749
14.	731.7	78.1	58.2	5.6	141.9	393.0	156.1	549.0	.750
15.	737.5	78.3	58.3	5.6	142.2	397.7	156.5	554.3	.752
16.	743.5	78.7	58.5	5.6	142.8	401.8	157.6	559.4	.752
17.	749.8	79.2	58.7	5.7	143.6	405.9	158.7	564.7	.753
18.	756.[illegible]	[illegible]			[illegible].5	410.3	159.9	570.2	.754
19						[illegible].8	161.2	576.0	.755
							[illegible].4	581.9	.756
								[illegible].9	.757

Note: Units are langleys/day.

PYROELECTRIC TURBIDITY METER

During 1975 the feasibility of developing turbidity meters using pyroelectric detectors was investigated. Computer programs were written and a trial run was made on a prototype instrument, developed by NBS for laser calorimetry, to check on the suitability of such instruments for GMCC use. Since the time that initial work on this project was started, electrically calibrated pyroelectric detectors have become commercially available.

OTHER SUPPORTING COMPUTER CALCULATIONS

In addition to the computer programs directly concerned with data processing and analysis (sec. 4.5.2) and with the radiation climatology, several other supporting programs have been prepared. Chief among these are: 1) Computations of Rayleigh optical depths versus wavelength using the latest value for the depolarization factor given by Rudder and Bach (1968) for N_2. 2) Computations of the air mass values using the *U.S. Standard Atmosphere 1962* up to 90 km for 0.40, 0.45, 0.50, 0.55, and 1.06 μm wavelengths. Comparison with tabulations by Kasten (1964) showed agreement to within 1 part in 10,000 at nearly all solar zenith angles. 3) Computations of the air mass values for the beginning of each minute of every day for Mauna Loa, Barrow, and Boulder. (These tabulations are very useful for hand checking the results of our data and for the sunphotometer calculations.)

ACQUISITION OF SOLAR TRACKER

A solar tracker was acquired from Carson Astronomical Instruments, Inc. in 1975. It has a hexagonal spar for the mounting of more than one instrument and has a tracking accuracy of better than 1 arc minute. A dome for housing this instrument is being built. Modifications to the original instrument have included a new holder for the solar tracking head and a holder for a pyranometer for pyrheliometer intercomparisons which are planned.

4.6 Precipitation Chemistry Measurements

The analysis of precipitation for its chemical constituents has been a part of scientific investigation for over 200 years. Atmospheric chemistry, meteorology, geochemistry, limnology, agriculture, and ecology are among the disciplines that have recognized the importance of understanding the chemistry of precipitation. Scientists in these various fields have conducted a multitude of precipitation chemistry studies.

Although all this work forms a solid basis of reference for global and regional monitoring, it is important to define the methods, techniques, and purpose of precipitation chemistry to answer a basic question in terms of the GMCC program, i.e., how does a particular measurement at a baseline site contribute to our monitoring of climatic change? To answer this question one

must realize that precipitation chemistry data can be viewed in two ways. First, the precipitation that is collected represents complex processes in the atmosphere which include condensation of water on particles, capture of particles and gases in clouds, coagulation of cloud droplets to form rain, and finally the scavenging of gases and particles below a cloud. An ice phase may also be involved to complicate the picture. Actual "climatic changes" may participate in each of these processes in the atmosphere. By measurement of sulfate, nitrate, and other constituents over a long period of time the gross integrated index of these different chemicals can point to trends. But even if trends are detected, meteorological and other related data must be used in interpreting the results and subsequently relating these to the concept of "climate".

Thus, precipitation chemistry data can be used as an index of compounds that may influence the climate--SO_2, sulfate aerosols, ammonia, chloride, and others. An improved solution would be to measure these gases and aerosols directly in and out of clouds at several levels in the atmosphere for concentration, chemical composition, size distribution, and other pertinent parameters. Such measurements are not yet practical in monitoring programs and can be obtained only on a research basis with newly developed techniques. Thus, the gross measurements provided by precipitation chemistry must suffice until we have more sophisticated, economical, and direct methods of sampling.

A second kind of information that can be gathered from precipitation chemistry concerns the deposition of materials to the Earth's surface. This information becomes extremely important in evaluating the Earth's geochemical and biological systems. Knowledge of the chemical cycles at the atmosphere-Earth interface will be helpful in recognizing changes in the biosphere. Such biological changes may eventually have indirect climatic effects.

A case in point is the increase in acidity of precipitation both in the northeastern United States and Scandinavia which has been postulated to be caused by an increase in nitric oxide and sulfur dioxide in the air. Reduced tree growth and decreasing fish population are a direct consequence of this anthropogenic and regional phenomenon. An even more subtle problem could be the long term synergistic effects caused by this change in precipitation composition. Such trends in precipitation chemistry make it imperative to establish baseline measurements in pristine areas such as those around the present GMCC observatories. These data would show to what extent these regional trends may have expanded to a global scale.

4.6.1 New Precipitation Chemistry Activities in 1975

Because the World Meteorological Organization (WMO) has established precipitation chemistry as one of the required programs at baseline and regional stations, the WMO sponsored an expert meeting on wet and dry deposition (WADEM) in November 1975 (Kronebach, 1975). The purpose of this meeting was to coordinate international studies of precipitation chemistry. In the final report, the participating scientists suggested preferred sampling techniques, analysis procedures and data processing methods. The recommendations will be used to revise WMO Manual No. 299 "WMO Operations Manual for Sampling and

Analysis Techniques for Chemical Constituents in Air and Precipitation." Such coordination and standard setting has become imperative because of the great interest expressed by Australia, Kenya, Argentina and other countries in establishing regional and baseline sites.

Besides participating in the WMO-Expert meeting, Dr. J. Miller of the GMCC staff participated in the unilateral exchange program under the US-USSR agreement on cooperation in the field of environmental protection. The purpose of his 4-week visit to the Soviet Union was twofold: First, to investigate the work being done in the USSR in geophysical monitoring, especially precipitation chemistry; second, to find areas of cooperation between the US and the USSR on the "effects of pollution on climate". The visit was successful in that Miller was able to work with Drs. Selezneva and Petrenchuk, two of the leading scientists in precipitation chemistry. It is hoped that through this exchange program Soviet scientists will visit one of the GMCC facilities in the future.

Nationally, the year 1975 was one of active scientific interest in precipitation chemistry. This interest was demonstrated in the Acid Rain Symposium where over 100 papers were presented. One of the most important studies to evolve in the last year has been the Cornell University intercomparison study jointly supported by an Environmental Research Laboratories (NOAA) grant and GMCC. Under this grant, Prof. Gene Likens and Dr. James Galloway have made significant contributions to establishing a scientific basis for the collection of precipitation and its analysis.

In this study precipitation was collected by several methods using apparatus of different designs. These differing methods and designs were investigated to determine which gives the most representative sample of precipitation for the determination of some 25 chemical parameters. The experimental site in Ithaca, New York, has 22 collectors of 10 different designs (Fig. 53) that collected in bulk (wet and dry deposition collected together), wet only (only rain and snow) and wet/dry (wet and dry deposition collected separately). In every sampling period, which varies from one day to one month, depending on the time variable being tested, the samples are analyzed for the following: conductivity, pH, Ca, Mg, Na, K, NH_4, NO_3, N_{total}, SiO_4, PO_4, P_{total}, Cl, SO_4, DOC, Zn, Cu, Mn, Fe, Al, Ni, Cd, Pb, Ag, DDT, DDE, Dieldrin and PCB's.

Major conclusions of this study are:

a. Precipitation samples must exclude dry deposition if accurate information on the chemical content of precipitation is required.

b. Substantial contamination results when glass and plastic collectors are used to sample precipitation for inorganic and organic components, respectively.

c. The inorganic components of precipitation samples of low pH (3.5-4.5), with the exception of PO_4 and Cl, exhibit no significant change in concentration when stored at 4°C for a period of eight months.

Figure 53. Site of Cornell University intercomparison of precipitation collection methods.

d. If quantitative information on the chemical composition is required, precipitation samples should be collected at intervals no longer than 1 week if immediate collection is not possible (Galloway and Likens, 1976).

To apply the results of the Cornell comparison to study of regional wet deposition of air pollutants, especially sulfur, four regional collection sites will be established under a cooperative effort by Battell Northwest and NOAA and funded by the Energy Research and Development Administration (ERDA), Fig. 54. The stations form a "baseline" through the northeast U.S. where changing energy resources will increase the use of high sulfur fuels in the years to come. State University of New York (SUNY) at Albany, Cornell University, Pennsylvania State University and University of Virginia will participate in the project. It is hoped that with careful siting, collection, and analysis, these stations will produce long-term quality precipitation chemistry data especially useful in the evaluation of environmental changes.

Another area that has been investigated under modest GMCC funding is that of fog collection for chemical analysis. It was found that metal fog collectors at Mauna Loa contaminated the samples. To solve this problem, Mr. Ray Falconer of SUNY has designed a plastic fog collector which will be tested at Whiteface, N.Y. in 1976. Eventually one will be placed at Mauna Loa (Fig. 55).

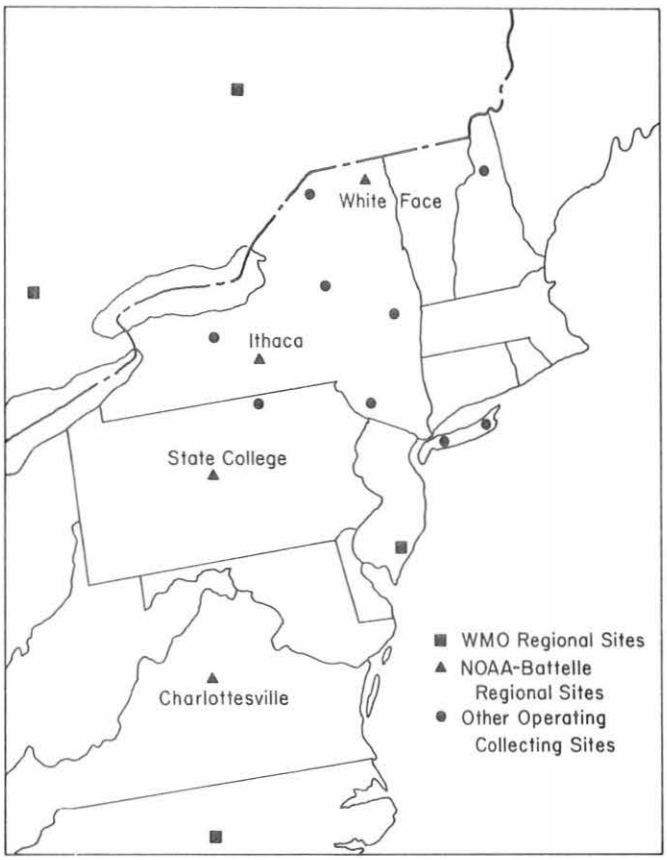


Figure 54. Northeast U.S.--Canada regional network of precipitation collection stations.

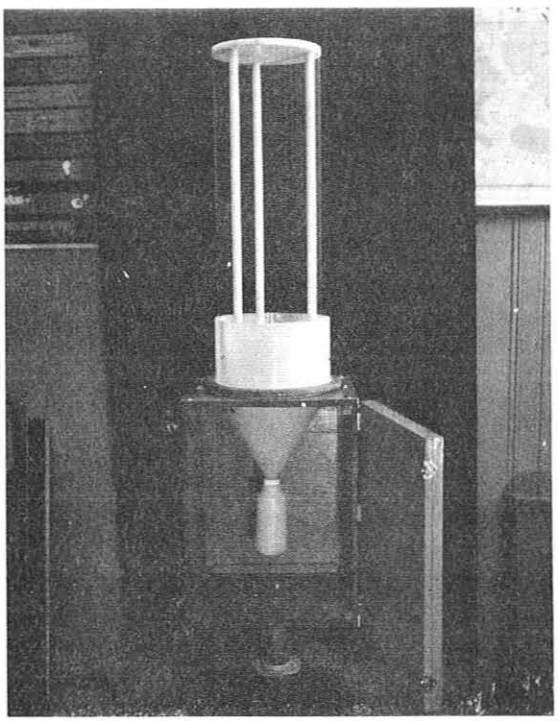


Figure 55. Plastic fog collector to be tested at Whiteface, N.Y., in 1976.

4.6.2 Baseline Precipitation Chemistry

During 1975, Mauna Loa, Barrow, and Samoa began pH and conductivity measurements using pH meters, conductivity bridges, electrodes, chemicals, and bulk collectors. It is hoped that the in-situ measurements can be expanded to include sulfate, chloride, and other important ions. Table 19 is an overview of the measurement programs at the three sites. The ERDA program is described in Section 5.1.3. The data from the EPA collector are published in *Atmospheric Turbidity and Precipitation Chemistry Data for the World.*

Table 19. Precipitation Chemistry Measurements at GMCC Baseline Sites

Mauna Loa	
GMCC	pH, conductivity (daily, weekly at three sites).
EPA	pH, conductivity, SO_4, NO_3, NH_4, Cl, F, Ca, Cu, Fe, K, Mg, Mn, NA, Ni, Pb, Zn, (monthly at MLO).
ERDA	pH, SO_4, Cl, NO_3, Pb, Ni, Ce, V (monthly MLO 1976).
Barrow	
GMCC	pH (weekly at four sites).
EPA	same as Mauna Loa.
Samoa	
GMCC	pH measurements to begin in 1976.
EPA	same as Mauna Loa.
ERDA	same as Mauna Loa.

MAUNA LOA

Data of Mauna Loa pH measurements included in GMCC *Summary Report 1974* were those collected in standard rain gauges (metal). New plastic collectors have been installed since then at the three main sites--Hilo, Kulani Mauka, and Mauna Loa Observatory. Values for the latter half of 1975 are shown in Fig. 56. The decrease of pH values with ascent is demonstrated in Fig. 57.

To show the validity of weekly sampling versus event sampling for pH determination, Fig. 58 shows the small difference between the composite weekly collection and the weighted average of all the events for that given week. The weighted averaged values are somewhat lower than the composite.

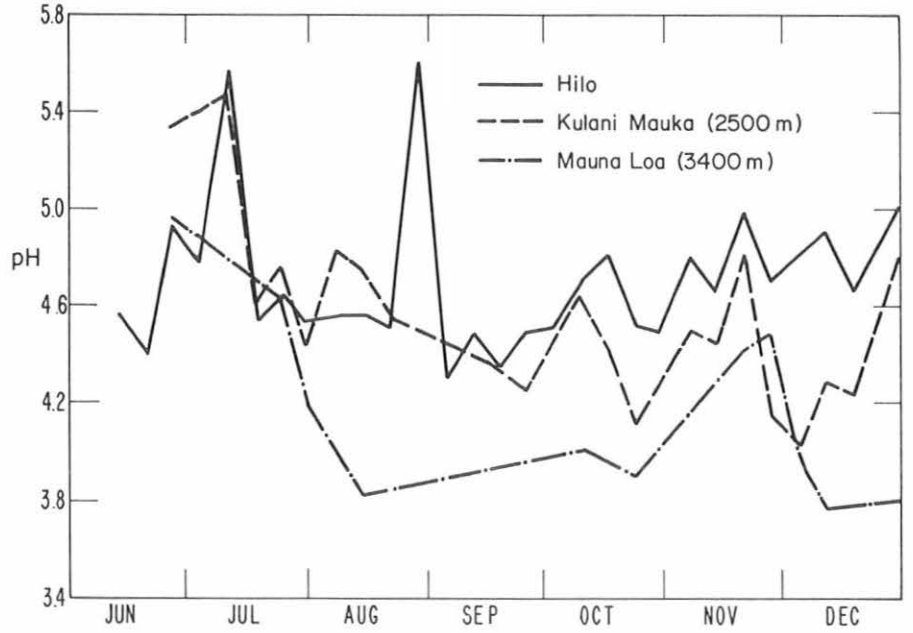


Figure 56. Weekly pH values in Hawaii.

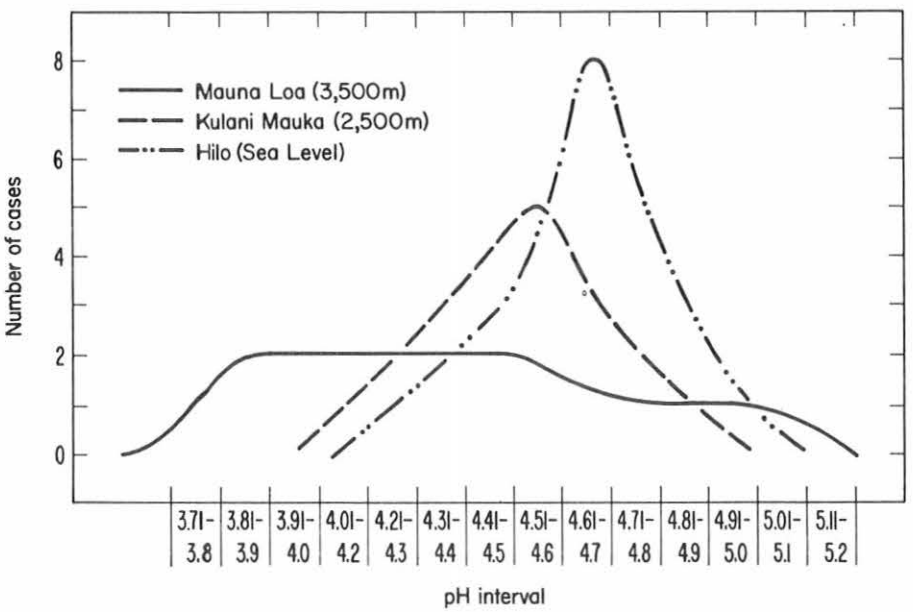


Figure 57 Histogram of pH values in Hawaii.

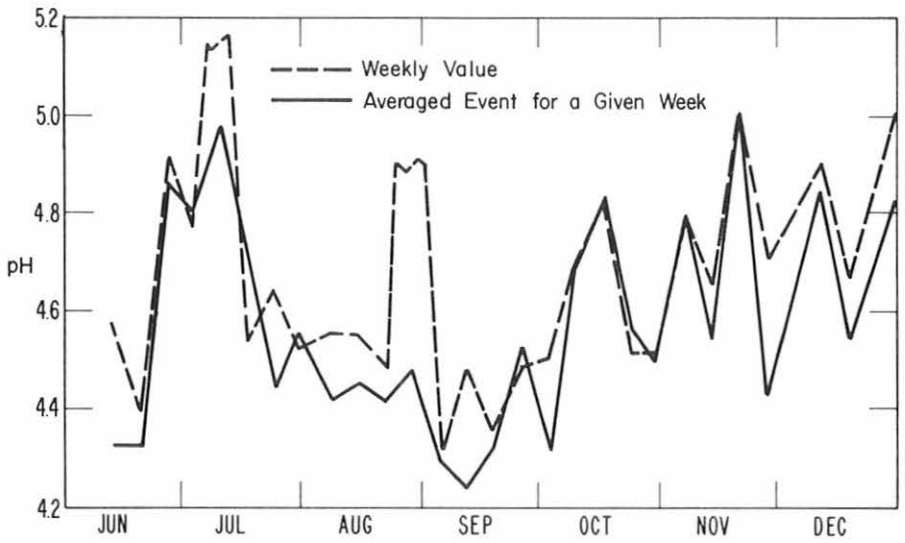


Figure 58. Comparison of weekly sampling with event sampling at Hilo, Hawaii for pH determination.

BARROW

The difficulty of obtaining representative precipitation samples for chemical analysis in the Arctic environment is well known. Conventional collection of representative samples at Barrow is especially difficult, because of the small amount of precipitation and the added factor of blowing snow.

To approach the problem of collection and analysis of precipitation in such an environment, a local program of snow collection for pH measurements was established. From February 19 to May 19, 1975, snow was collected weekly at four sites, 25 meters north, east, south, and west of the observatory. Samples were taken from newly fallen snow and old snow underneath. The ob server was careful not to contaminate the sample during collection. By standard procedures, pH values were determined on the eight samples. Table 20 shows the results for the winter season. These data must be considered preliminary since collection and measurement techniques are still to be defined.

Table 20. pH Values of Snow Measured at Barrow from February 19 to May 19, 1975.

Average	North	South	East	West
New Snow	4.80	4.56	4.94	4.95
Old Snow	5.06	4.89	5.14	5.12
Total	4.90	4.72	5.03	5.03

SAMOA

Special studies of pH in precipitation should begin in 1976.

4.6.3 Regional Precipitation Chemistry

In 1970, a joint program was begun by NOAA and EPA to establish WMO regional sites in the United States. Without formal site surveys, ten National Weather Service (NWS) stations were chosen as regional collection points. The only criterion for the choice was that the stations not be in urban areas. Table 21 and Figure 59 show the sites. Only two, Caribou and Huron, had been included in previous Public Health Service networks.

Table 21. WMO Regional Sites in the United States

Site	Elevation (m)	Coordinates		WMO ID No.
Bishop, Calif.	1252	37°22'N	118°22'W	72480
Alamosa, Calif.	2297	37°27'N	105°52'W	72462
Salem, Ill.	177	38°39'N	88°58'W	72433
Caribou, Maine	191	47°41'N	68°03'W	72712
Meridian, Mass.	94	32°29'N	88°45'W	72234
Atlantic City, N.J.	74	35°52'N	78°47'W	72407
Pendleton, Oreg.	456	45°41'N	118°51'W	72688
Huron, S. Dak.	393	44°25'N	105°52'W	72654
Victoria, Tex.	36	28°51'N	96°55'W	72255

An informal arrangement was made that NWS would provide the sites and Air Resources Laboratories would provide evaluation of the data. EPA would take care of the chemical analysis of the samples at the Quality Assurance and Environmental Monitoring Lab. This program has been operated in this manner from 1972 to the present.

The data from the regional sites are reported in *Atmospheric Turbidity and Precipitation Chemistry Data for the World*.

4.6.4 Special Study

In April 1974, a volunteer program was established in the Washington, D.C., area to determine pH and precipitation amounts. The network now consists of six collecting sites. The purpose of the network is to test field methods of precipitation collection that could be transferred to regional and

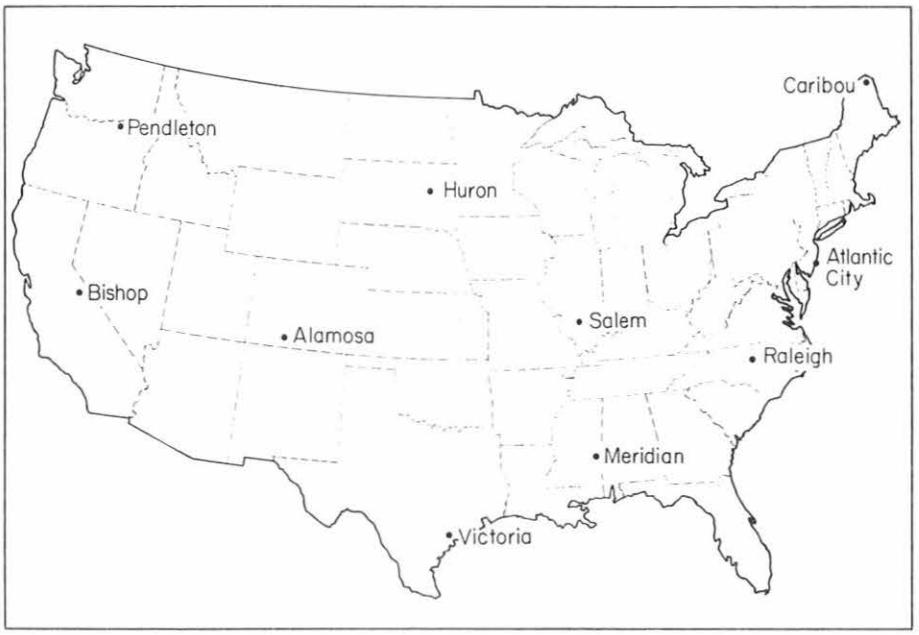


Figure 59. WMO regional stations.

baseline sites which generally have only limited chemistry facilities. The pH data should be typical of values for the northeastern United States. A summary of the 1975 results at the six sites is shown in figure 60.

4.6.5 Plans

Plans for the precipitation chemistry program within GMCC are:

a. Establishment of in-situ chemical measurements in precipitation at the baseline observatories.

b. Site evaluation by both multiple collection at the baseline observatories and meteorological analysis using air trajectories.

c. Replacement of present open-close collectors at both regional and baseline sites with more reliable collectors.

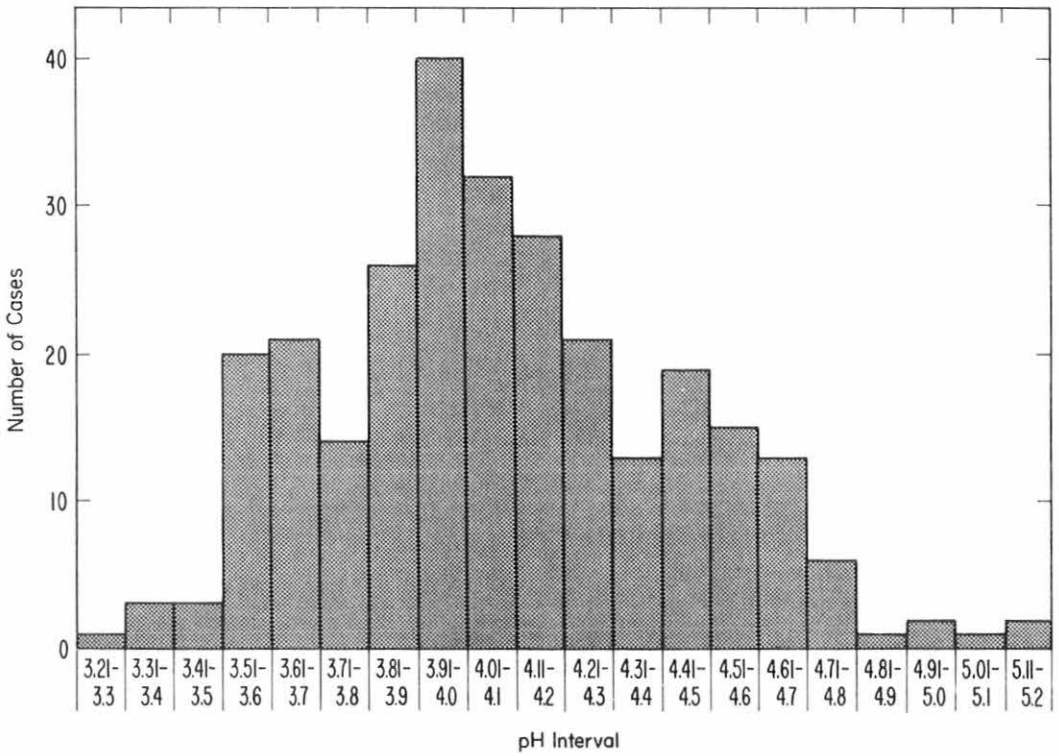


Figure 60. Histogram of pH values in Washington, D.C. (six stations), 1975.

5. COOPERATIVE MEASUREMENT PROGRAMS

This section provides an opportunity for the major cooperative program investigators to review their activities at the GMCC Observatories and to summarize some of their data. A complete listing of the cooperative programs is included in the Tables under Section 3.

5.1 Mauna Loa Observatory

5.1.1 Sunburning Ultraviolet Meter

Daniel Berger, Principal Investigator
Temple University
School of Medicine/Skin & Cancer Hospital

The Sunburning Ultraviolet Meter, measures the skin-sunburning effectiveness of solar energy. The spectral response of the meter is similar to the skin's erythema action spectrum. The data consist of the dose during each half hour of sunburning ultraviolet measured throughout the day on a horizontal plane.

It is believed that the action spectrum of skin cancer is like that of sunburn, and the meters have been placed in several locations where data on the occurrence of skin cancer have been previously gathered: Oakland, Ft. Worth, Minneapolis, Des Moines, Albuquerque, El Paso, Philadelphia, and two sites in Australia. The short wavelength end of the ultraviolet spectrum, which induces sunburn, is strongly affected by ozone concentration. The meter has been installed in three locations that have Dobson ozone spectrophotometers in order to correlate sunburn effect with ozone changes: Bismarck, Tallahassee, Mauna Loa. Other sites have been chosen to provide a better understanding of the effects of latitude, altitude, and local atmospheric conditions on the measured parameter: Warsaw, Poland; Davos, Switzerland; Honeybrook, Pa.

In 1975 eleven stations in the United States continued to gather data. Two stations in Australia also continued their observations. The single station in Europe was supplemented by two others in June.

Annual calibrations of each station were made. Annual changes have averaged 2% with maximum variations of 7%.

The 1974 results have been analyzed and published by the National Cancer Institute Publication DHEW NO (NIH) 76-1029, "Measurement of UV Radiation in the U.S. and Comparisons with Skin Cancer Data." The conclusions of this report are applicable to any other single year in which the stations are essentially the same.

An expanded network is projected for 1976. Six additional stations in the Western Hemisphere and an additional station in Europe are planned. The climatology developed should be useful to a variety of disciplines including epidemiology, biology, and meteorology.

5.1.2 Atmospheric Electric Measurements

William Cobb, Principal Investigator
Atmospheric Physics and Chemistry Laboratory (APCL), NOAA

In April 1975, an agreement was reached between GMCC and APCL concerning atmospheric electricity measurements at three of the GMCC stations. The agreement calls for APCL to develop and test a measurement system for potential gradients, air-Earth current, and conductivity, to install the system at Mauna Loa, and to turn the equipment over to the staff for routine operation. The purpose of the program is to repeat the measurements made in 1960 and again in 1968 in order to detect any secular changes in the atmospheric electric climate at the observatory.

Instruments to measure the potential gradient, the air-Earth current density, and the atmospheric electrical conductivity were installed at Mauna Loa in October 1975. The potential gradient and air-Earth current sensors are the same type as the instruments installed at the South Pole (see Section 5.3.1). The conductivity sensors, positive and negative, are the same "Gerdien" cylindrical condensor systems used in previous MLO measurement expeditions. All parameters are monitored by a strip chart recorder and are also fed into the station's data acquisition system.

This equipment will be rotated between Mauna Loa, Barrow, and Samoa at an interval to be determined by the scientific need so that for each station baseline values of the atmospheric electric climate will be developed and checked at 5- to 10-year intervals for possible secular changes. No significant data analysis for Mauna Loa has been completed during 1975.

5.1.3 High Volume Aerosol and Precipitation Collection Programs

Herbert L. Volchok, Principal Investigator
Health and Safety Laboratory (HASL), ERDA

The two HASL programs at the GMCC stations have been part of much larger monitoring research efforts of this laboratory. One involves high volume, continuous sampling of the surface air aerosol; the other samples the cations in precipitation by an ion exchange resin column. Both programs have similar objectives: the study of spatial and temporal distributions of particular stable and radioactive species, in air and precipitation respectively.

The precipitation program was initiated at both Barrow and Mauna Loa in 1959. The Mauna Loa station has continued in this study through 1975; Barrow essentially discontinued sampling at the end of 1967. The samples from this program were analyzed only for Sr-90. All of the data produced are reported quarterly (Hardy, 1975). The period of 1967 through 1975 for Mauna Loa has been summarized in Table 22. A general description of the program and data interpretation is published annually (see Volchok, 1975).

The surface air sampling at Mauna Loa and the South Pole was actually started in the mid-1950s by the Naval Research Laboratory (Lockhart et al., 1964, 1965) and continued through 1962. HASL took over the program in 1963,

Table 22. Summary of Monthly Fallout Deposition Collections at Mauna Loa Observatory†

		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	CUM. TOTAL
1967	PRECIPITATION	8.81	0.86	10.49	5.23	6.98	5.10	9.30	5.87	3.38	4.24	11.20	--	71.46
	SR-90	0.03	0.01	0.06	0.05	0.04	0.01	0.03	0.01	0.01	*	*	*	0.25
	SR-90 CONCENTRATION	0.34	1.16	0.57	0.96	0.57	0.20	0.32	0.17	0.30	--	--	--	
	SR-89/SR-90	25.30	*	6.50	4.80	*	*	*	*	*	*	*	*	
1968	PRECIPITATION	5.08	3.91	8.64	11.25	4.04	4.04	2.41	5.43	11.53	5.61	1.17	9.24	72.35
	SR-90	0.01	*	0.05	0.11	0.02	0.05	0.02	0.04	0.04	0.01	0.02	*	0.37
	SR-90 CONCENTRATION	0.20	--	0.58	0.98	0.50	1.24	0.83	0.74	0.35	0.18	1.71	--	
	SR-89/SR-90	22.00	*	2.40	1.20	*	*	*	4.20	4.20	*	*	*	
1969	PRECIPITATION	13.44	2.72	4.60	2.46	1.65	0.05	0.64	0.33	0.99	1.45	*	1.42	29.75
	SR-90	0.02	0.02	0.04	0.02	0.02	*	*	*	0.02	0.01	*	0.01	0.16
	SR-90 CONCENTRATION	0.15	0.74	0.87	0.81	1.21	--	--	--	2.02	0.69	--	0.70	
	SR-89/SR-90	*	*	7.70	8.50	5.50	*	*	*	*	*	*	*	
1970	PRECIPITATION	2.28	2.27	*	3.28	3.63	0.05	0.33	3.53	0.28	0.91	1.27	4.83	22.66
	SR-90	*	0.01	*	0.11	0.04	*	0.01	0.01	*	*	*	0.02	0.20
	SR-90 CONCENTRATION	--	0.44	--	3.35	1.10	--	3.03	0.28	--	--	--	0.41	
	SR-89/SR-90	--	--	--	--	--	--	*	*	*	*	--	*	
1971	PRECIPITATION	18.11	0.64	0.93	7.01	--	0.79	--	0.28	1.17	--	6.48	0.64	36.05
	SR-90	0.02	0.01	0.01	0.14	0.05	0.04	0.02	*	0.01	*	*	*	0.30
	SR-90 CONCENTRATION	0.11	1.56	1.08	2.00	--	5.06	--	--	0.85	--	--	--	
	SR-89/SR-90	5.00	--	--	--	--	--	--	--	--	--	--	--	
1972	PRECIPITATION	0.84	1.85	2.06	2.08	3.51	1.40	3.81	0.38	1.65	--	0.64	--	18.22
	SR-90	0.10	0.02	0.02	0.02	0.02	0.01	0.03	*	*	*	*	0.04	0.26
	SR-90 CONCENTRATION	11.90	1.08	0.97	0.96	0.57	0.71	0.79	--	--	--	--	--	
	SR-89/SR-90	--	--	--	--	--	--	--	--	--	--	--	--	
1973	PRECIPITATION	--	0.51	--	0.08	3.05	--	4.52	--	3.81	--	14.12	2.54	28.63
	SR-90	*	*	*	*	*	*	*	*	*	*	*	*	0.00
	SR-90 CONCENTRATION	--	--	--	--	--	--	--	--	--	--	--	--	
	SR-89/SR-90	--	--	--	--	--	--	--	--	--	--	--	--	
1974	PRECIPITATION	5.66	--	--	--	4.83	1.12	2.54	*	4.22C	4.22C	--	--	22.59
	SR-90	*	0.04	0.05C	0.05C	0.05	0.02	*	*	*	*	--	--	0.21
	SR-90 CONCENTRATION	--	--	--	--	1.04	1.79	--	--	--	--	--	--	
	SR-89/SR-90	--	--	--	--	--	--	--	--	--	--	--	--	
1975	PRECIPITATION	9.02	6.48	1.98	--	*	0.76	0.38	--	--	--	--	--	18.62
	SR-90	0.03	0.04	*	*	*	*	*	--	--	--	--	--	0.07
	SR-90 CONCENTRATION	0.33	0.62	--	--	--	--	--	--	--	--	--	--	
	SR-89/SR-90	--	--	--	--	--	--	--	--	--	--	--	--	

--: Data not available
*: *Zero or trace*
A: *Approximate*
B: *Lower limit of reported data*
C: *Proportioned from originally consolidated data*

†: *Precipitation in centimeters*
SR-90 in Milli-Curie/square kilometer
SR-90 Concentration in Pico-Curie/liter
SR-89/SR-90 = Ratio

but for logistical reasons sampling at the South Pole was terminated and was not resumed there until 1970. Sampling started at Barrow in 1975 and is scheduled to start at Samoa in 1976.

In the course of this study, the samples have been analyzed for a variety of radionuclides in response to various stimuli such as timing of the nuclear weapons tests, tracer experiments, and accidental releases. Routine analysis for elemental lead was begun in 1966. The current program includes analyses for Sr-90, Zr-95, Cs-137, Cs-144, Pb-210, plutonium, and stable Pb. As in the precipitation program, the data are published quarterly (Volchok et al., 1975). Data from Mauna Loa and South Pole for 1974 and 1975 are summarized in Tables 23 and 24. Table 25 summarizes the data from the Barrow program which was initiated in September 1975.

Plans for the immediate future include: (a) providing both the Mauna Loa and Samoa sites with instruments to separate wet from dry fallout, (b) aerosol sampling at Mauna Loa as a function of wind direction, (c) initiating aerosol sampling at Samoa, and (d) increasing the scope of non-nuclear analyses of the samples (pH, $SO_4^{=}$, NO_3^{-}, Cl^{-} and additional trace metals). These program changes will all be effected in 1976.

5.1.4 Tritium Measurements

Göte Östlund, Principal Investigator
Rosenstiel School of Marine and Atmospheric Sciences
University of Miami

The Tritium Laboratory of the Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, began atmospheric tritium sampling at Mauna Loa Observatory in August 1971. The activity of water vapor and the mixing ratio of tritiated water vapor (HTO) are determined, as is the mixing ratio of tritium gas (HT). The system is described in Östlund and Mason (1974). First, all the water vapor is absorbed in one "trap" of molecular sieve. In a succeeding trap, the atmospheric hydrogen species are combusted to water which is absorbed in-situ. At Mauna Loa, air is processed at a rate of 2 ℓ/min. Two sample runs are made per week, each normally 48 hours long. The traps are sent to Miami for extraction and analysis.

Mauna Loa Observatory serves as the Northern Hemisphere baseline for a network of similar samplers that includes Fairbanks, Alaska; Miami, Fla.; and Baring Head, New Zealand. The 1975 data from all four stations are shown in Fig. 61. The stratosphere contains most of the atmospheric HTO, and the effect of the spring leak on the HTO mixing ratio (very prominent at Fairbanks in early summer) is seen to be removed by precipitation and air-sea exchange prior to arrival at Mauna Loa Observatory. During 1975, the pulses of HT released by underground nuclear test (a major HT source) were below the magnitude needed for unambiguous detection at Mauna Loa Observatory. In previous years, notably 1973, large injections were detected as a step increase in the HT mixing ratio. (See Mason and Östlund, 1974, for a report of that event.)

At the end of 1975, a new HT/HTO sampler was being installed at Mauna Loa Observatory. This unit has dual gas trains, which permit separation of

Table 23. Surface Air Concentrations of Selected Elemental Species in Mauna Loa, Hawaii

SURFACE AIR CONCENTRATION IN MALNA LCA, HAWAII DLRING 1974

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	ALG.	SEP.	CCT.	NCV.	DEC.
GAMMA (CPM/CU.M)	0.032	0.001	0.138	C.1C3	C.C66	C.185	C.C60	C.036	0.035	0.033	0.046	C.057
BE- 7 (FCI/CU.M)	136.00	191.CC	247.CC	213.CC	201.CC	194.CC	224.CC	247.00	161.00	186.CC	218.CC	213.CC
SR- 9C (FCI/CU.M)	0.67	2.47	4.28	3.47	3.8S	3.18	1.76	C.99	0.66	0.71	0.87	1.24
ZR- 95 (FCI/CU.M)	14.30	38.2C	52.8C	3S.9C	2S.1C	18.6C	32.9C	19.70	15.60	15.40	26.40	28.9C
CS-137 (FCI/CU.M)	0.83	3.65	6.90	6.84	7.42	5.1S	2.72	1.95	0.90	1.12	1.62	2.08
CE-144 (FCI/CU.M)	13.10	47.8C	88.8C	84.6C	81.1C	52.6C	29.1C	19.30	11.80	12.30	20.90	26.2C
STABLE PB(LG/CL.M)	8.63	4.29	5.04	4.14	2.62	3.22	8.35	1C.10	4.44	4.51	3.25	--
PB-21C (FCI/CU.M)	--	--	--	--	--	--	7.55	8.42	7.77	6.60	7.58	5.91
PL-239 (ACI/CL.M)	15.50	52.60	101.CC	77.CC	1CS.CC	83.9C	31.3C	2C.1C	15.30	14.80	16.70	28.9C

SURFACE AIR CONCENTRATION IN MALNA LCA, HAWAII DLRING 1975

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	ALG.	SEP.	CCT.	NCV.	DEC.
GAMMA (CPM/CU.M)	0.053	0.058	0.044	C.C4S	C.C34	C.C22	C.C16	C.C13	0.010	0.005	0.008	C.C1C
BE- 7 (FCI/CU.M)	199.00	184.00	231.00	225.CC	307.CC	24S.CC	231.CC	259.00	276.00	188.CC	226.00	246.00
SR- 90 (FCI/CU.M)	1.30	2.06	1.52	2.4S	2.81	1.45	1.C7	C.43	0.30	--	--	--
ZR- 95 (FCI/CU.M)	28.70	23.10	14.70	11.2C	8.37	3.4S	1.51A	C.36	0.08B	0.27A	0.25A	C.23
CS-137 (FCI/CU.M)	2.68	3.44	2.85	3.26	3.9C	2.21	1.38	C.59	0.46	0.44	0.43	0.56
CE-144 (FCI/CU.M)	33.30	40.60	28.3C	28.3C	33.3C	15.1C	8.1C	3.52	2.23	1.13	1.34	1.25
STABLE PB(LG/CL.M)	3.76	4.10	2.26	1.5S	2.82	1.9B	4.42	3.94	3.23	--	--	--
PB-210 (FCI/CU.M)	5.28	8.97	11.3C	15.4C	17.1C	12.CC	1C.5C	9.71	9.15	--	--	--
PL-239 (ACI/CU.M)	30.60	61.30	35.2C	5C.8C	4B.5C	3C.3C	1S.4C	8.66	9.26A	--	--	--

-- NC DATA

ERRORS ARE LESS THAN 20% EXCEPT:
A -ERRCR BETWEEN 20% AND 100%
B -ERRCR GREATER THAN 100%

Table 24. Surface Air Concentrations of Selected Elemental Species in South Pole

SURFACE AIR CONCENTRATION IN SOUTH POLE DURING 1974

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
GAMMA (CPM/CU.M)	0.006	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.006	0.012	0.021	0.013
BE- 7 (FCI/CU.M)	146.00	197.00A	119.00	84.20	59.50A	79.50	84.20	62.60	82.30	93.00	168.00	174.00
SR- 90 (FCI/CU.M)	0.43	0.41	0.26	0.12	0.12	0.12	0.11	0.15	0.11	0.19	0.28	0.42
ZR- 95 (FCI/CU.M)	--	--	6.43A	--	--	--	0.85	3.50	6.04	8.57	10.30	6.82
CS-137 (FCI/CU.M)	0.68	0.50	0.46	--	0.30	0.24	0.25	0.28	0.32	0.39	0.42A	0.86A
CE-144 (FCI/CU.M)	1.06A	--	0.69A	--	0.51A	--	0.51A	1.83A	1.91	3.00	4.45	4.21
STABLE PB(UG/CU.M)	0.93	3.01	1.67	2.84	7.07	1.44	7.65	3.06	4.59	2.15	--	2.37
PB-210 (FCI/CU.M)	--	0.90	0.54	0.34	0.43	0.68	0.60	0.48	0.36	0.44	0.77	1.27
PU-239 (ACI/CU.M)	7.67	4.18A	2.25A	3.85A	2.50A	3.18A	1.92A	3.73A	0.35B	2.66A	5.12A	8.42

SURFACE AIR CONCENTRATION IN SOUTH POLE DURING 1975

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
GAMMA (CPM/CU.M)	0.021	0.000	0.003	0.002	0.003	0.000	0.002	0.003	0.004	0.003	--	--
BE- 7 (FCI/CU.M)	166.00	179.00	117.00	105.00	103.00	72.80	104.00	113.00	108.00	87.80	--	--
SR- 90 (FCI/CU.M)	0.42	--	--	--	--	--	--	--	--	--	--	--
ZR- 95 (FCI/CU.M)	8.16	14.50	9.93	6.24	4.65	1.47A	1.83A	0.48	1.16	0.29A	--	--
CS-137 (FCI/CU.M)	0.75	1.11	0.73	0.76	0.71	0.23	0.35	0.42	0.32	0.47	--	--
CE-144 (FCI/CU.M)	5.55	10.30	6.97	7.32	7.05	2.61	3.86	2.91	2.57	1.58	--	--
STABLE PB(UG/CU.M)	2.17	--	--	--	--	--	--	--	--	--	--	--
PB-210 (FCI/CU.M)	1.76	--	--	--	--	--	--	--	--	--	--	--
PU-239 (ACI/CU.M)	13.10	--	--	--	--	--	--	--	--	--	--	--

-- NO DATA

ERRORS ARE LESS THAN 20% EXCEPT:
A -ERROR BETWEEN 20% AND 100%
B -ERROR GREATER THAN 100%

Table 25. Surface Air Concentrations of Selected Elemental Species in Barrow, Alaska During 1975

		SEP.	OCT.	NOV.	DEC.
GAMMA	(Counts per minute/cubic meter)	0.0001	0.0001	0.003	0.005
BE-7	(Femto-Curie/cubic meter)	28.00	29.30	65.60	65.10
SR-90	(Femto-Curie/cubic meter)	0.10	--	--	--
ZR-95	(Femto-Curie/cubic meter)	0.12A	0.10A	0.03A	--
CS-137	(Femto-Curie/cubic meter)	0.18	0.21	0.36	0.23
CE-144	(Femto-Curie/cubic meter)	0.68	0.48	0.66	0.71
Stable PB	(micrograms/cubic meter)	3.35	--	--	--
PB-210	(Femto-Curie/cubic meter)	4.22	--	--	--

Note: Errors are less than 20% except A = error between 20% and 100%.

the upslope and downslope wind regimes when activated by an external signal. A particulate sampler, being installed by the Energy Research and Development Administration, Health and Safety Laboratory, will provide the wind direction signal for our sampler.

5.1.5 Carbon Monoxide Measurements

Wolfgang Seiler, Principal Investigator
Max Planck Institute
Mainz, Federal Republic of Germany

EQUIPMENT

Because of several technical difficulties with the CO-instrument as well as difficulties in the transportation of calibration gases between Mainz, and Mauna Loa Observatory, the greatest part of the CO registrations obtained at MLO in 1973 and 1974 could not be used for analysis. On the basis of the experiences obtained in operating the CO-analyzer over an extended period at MLO, a new CO-analyzer was constructed in 1974 and installed at Mauna Loa Observatory in March 1975. The new CO-instrument is based on the same principles and chemical methods already described in GMCC Summary Report 1973. The detection limit of the CO-analyzer is 0.1 ppbv. The accuracy is ± 3% for a CO mixing ratio of 0.1 ppmv. The improved CO-instrument works continuously except for short periods every two weeks when the exchange of several chemicals, e.g., silver oxide, is being done. The zero point of the CO-instrument and the drift stability of the calibration curve are controlled automatically once every 90 minutes and once every 3 hours, respectively.

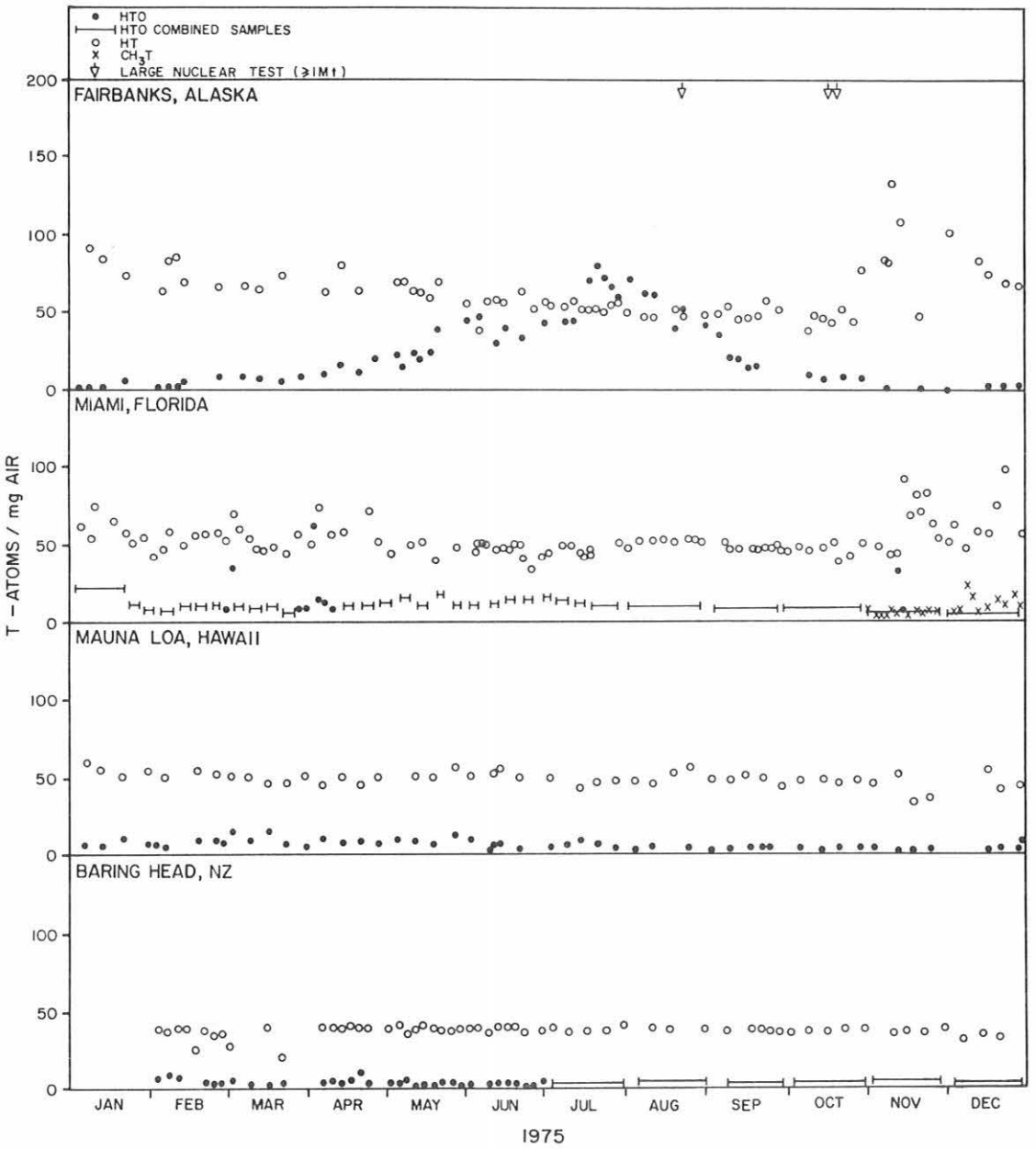


Figure 61. Atmospheric tritium at Fairbanks, Alaska; Miami, Florida; Mauna Loa Observatory, Hawaii; and Baring Head, New Zealand, 1975.

CALIBRATION

In 1973 and 1974 the CO-instrument was calibrated by using cylinders of compressed air with known CO-mixing ratios comparable with the expected ambient air mixing ratios at MLO in the range of 60-200 ppbv. The cylinders were filled and analyzed at the Max Planck Institute (Mainz), shipped to Mauna Loa Observatory and returned to Mainz after the cylinders had reached one-tenth of the original pressure. The recalibration of the cylinders at Mainz indicated an unreproduceable change of the CO mixing ratio in the cylinders with time, amounting to as much as ± 50%. As a consequence, the accuracy of the CO-calibrations at Mauna Loa was questionable and an analysis of the CO-registration was not possible. Furthermore, the loss of some cylinders during transport prevented additional checks.

Because of these difficulties a completely new calibration system was developed and installed at Mauna Loa in March 1975. The schematic diagram of this system is shown in figure 62.

In this system a constant flow (3 cm^3/min) of a CO calibration gas with a CO mixing ratio of 20 ppmv is diluted by a CO-free carrier gas (synthetic air passed over molecular sieve and hopcalite). The flowrates of both flow streams are measured by electrical flowmeters and registered continuously so that the CO mixing ratio of the air flow leaving the calibration device can be calculated. The calibration system was checked at Mainz for a period of about one year and found to produce a CO-calibration gas with an accuracy better than ± 5%. In addition, this system was checked after the installation at Mauna Loa for stability by a weekly calibration of the CO instrument using a manual but completely different calibration technique. Table 26 gives a comparison of the automatic and the manual calibration for several days. The data indicate a sufficiently high stability of the CO-calibration gas in the cylinder.

After one year of operation the tank pressure has decreased by only 5% of its original value of 150 bars. Thus, the CO-cylinder used in the automatic calibration device may last for a period of several years.

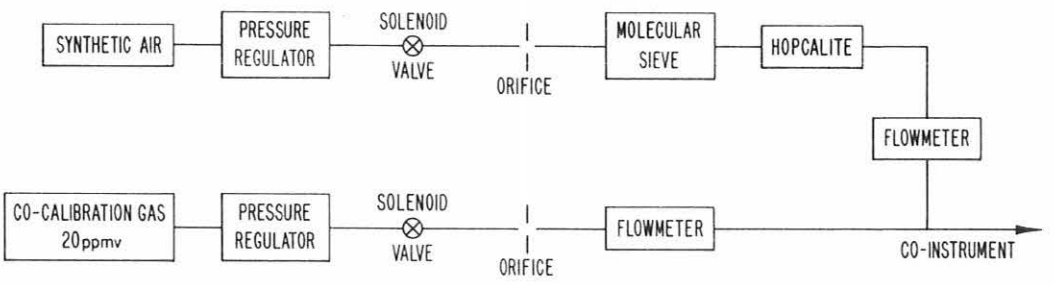


Figure 62. Calibration system installed at Mauna Loa in March 1975.

Table 26. Comparison of Calibration

Date:	4/16/75	5/7/75	6/11/75	7/16/75	8/6/75	10/15/75	10/24/75	12/3/75
Automatic calibration (ppmv)	0.115	0.112	0.111	0.111	0.111	0.112	0.111	0.125
Manual calibration (ppmv)	0.119	0.112	0.118	0.115	0.114	0.119	0.111	0.121

DATA

With the exception of some short interruptions the CO-instrument worked continuously from March to December 1975, so that for the first time a CO-registration is available for the case of unpolluted air masses over a longer time period. The registrations were evaluated at the Max Planck Institute at Mainz. Some results are shown in Fig. 63 to Fig. 65. Fig. 63 shows a section of the original CO-registration obtained on July 7, 1975, during the time period starting at 11 a.m. and ending at 4 p.m. During this period the zero point control was established five times and the automatic calibration of the instrument was performed three times. The CO-registration does not show any short-term fluctuations except a few spikes caused by automobile exhaust. The stable CO-mixing ratios indicated by the registrations are typical for Mauna Loa, indicating that this station is not influenced by anthropogenic activities. The three spikes occurring at the beginning and at the end of the registrations are caused by automobiles arriving and leaving the observatory.

Fig. 64 shows the CO-mixing ratio as a function of time-of-day averaged over a quarter of a year. It seems that carbon monoxide has a slight diurnal variation with a maximum during the afternoon and a minimum during the early morning. It is possible that these diurnal variations are due to the two distinct wind regimes observed at Mauna Loa with upslope winds during daytime and downslope winds during the nighttime, originating from regions below or above the trade wind inversions, respectively. If this interpretation is correct it would indicate a vertical CO-gradient in the lower and middle troposphere with higher CO-mixing ratios in the lower troposphere below the trade wind inversion. This behavior has been observed previously in the trade wind zone of the Atlantic Ocean at Teneriffa Island.

The most important feature of the CO-measurements at Mauna Loa appears to be the seasonal variation of the carbon monoxide mixing ratios shown in Fig. 65. There is a maximum during March/April with values of 0.12 - 0.13

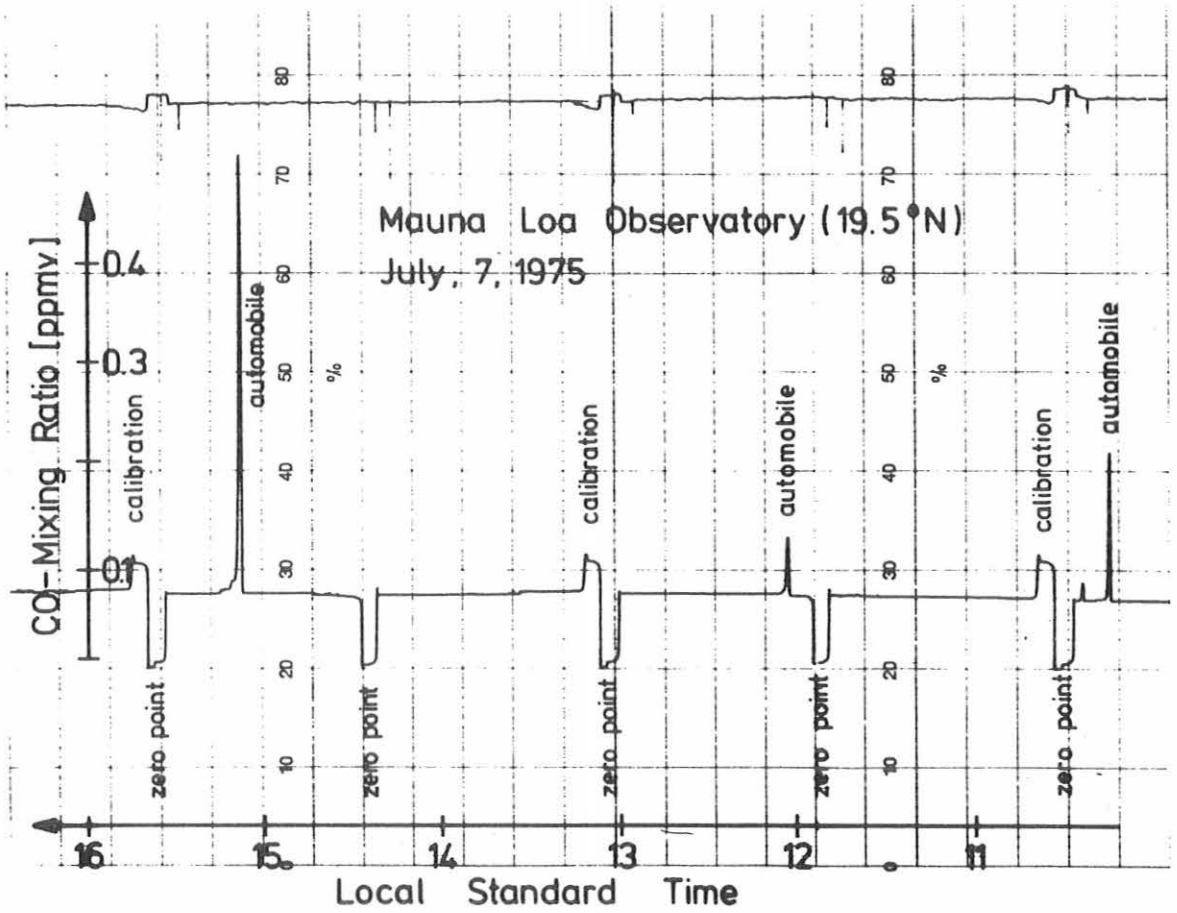


Figure 63. Section of the original CO-registration.

ppmv and a minimum in August/September with values of 0.07 - 0.08 ppmv. It is interesting that the maximum values are comparable with typical Northern Hemispheric CO-mixing ratios observed elsewhere, whereas the minimum values are characteristic for air masses of the Southern Hemisphere so that it looks as if Mauna Loa is seasonally influenced by the different hemisphere air masses because of the seasonal movement of the ITC. If this is the case, other pollutants like $CFCl_3$ and CF_2Cl_2 should show a similar seasonal trend. Such a trend, however, does not seem to exist. Another conceivable explanation is the influence of photochemical processes combined with a seasonal variation of the north-south transport of air masses in the sub-tropical regions of the Northern Hemisphere due to the seasonal change of the Hadley cell. Photochemical processes would include the oxidation of methane by OH-radicals resulting in the formation of carbon monoxide, and the oxidation of carbon monoxide by the same radicals. Further data must be obtained to substantiate the observed seasonal behavior and to find the correct explanation for the observations.

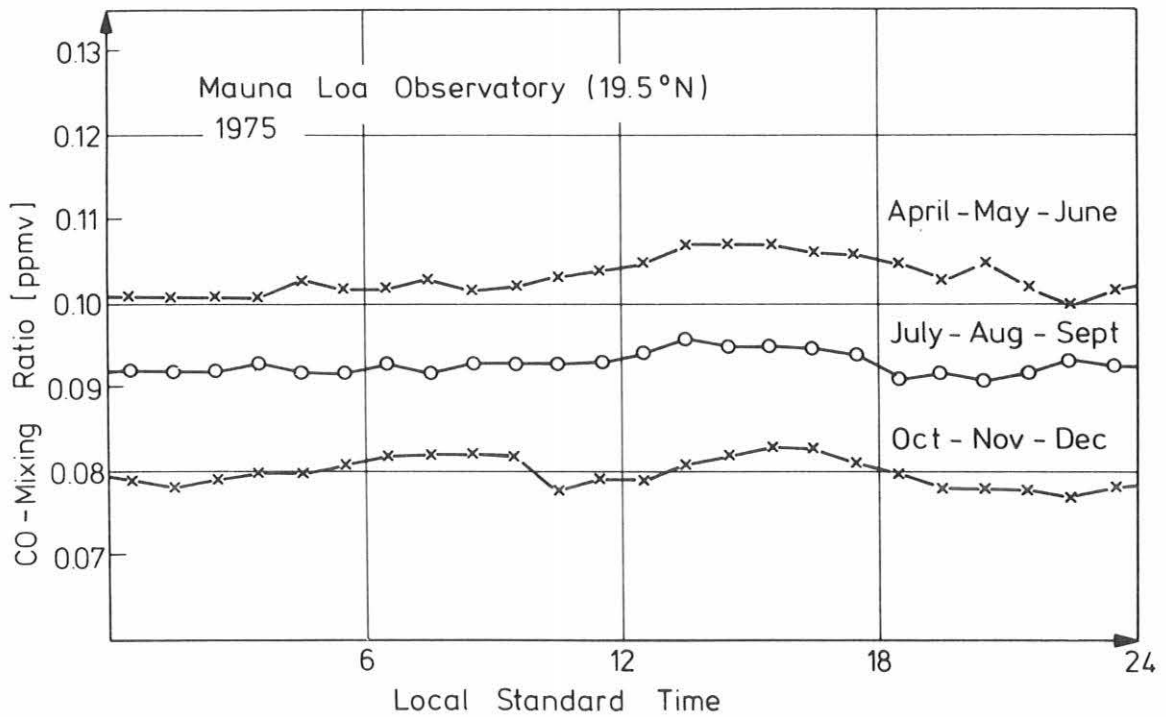


Figure 64. CO mixing ratio as function of time.

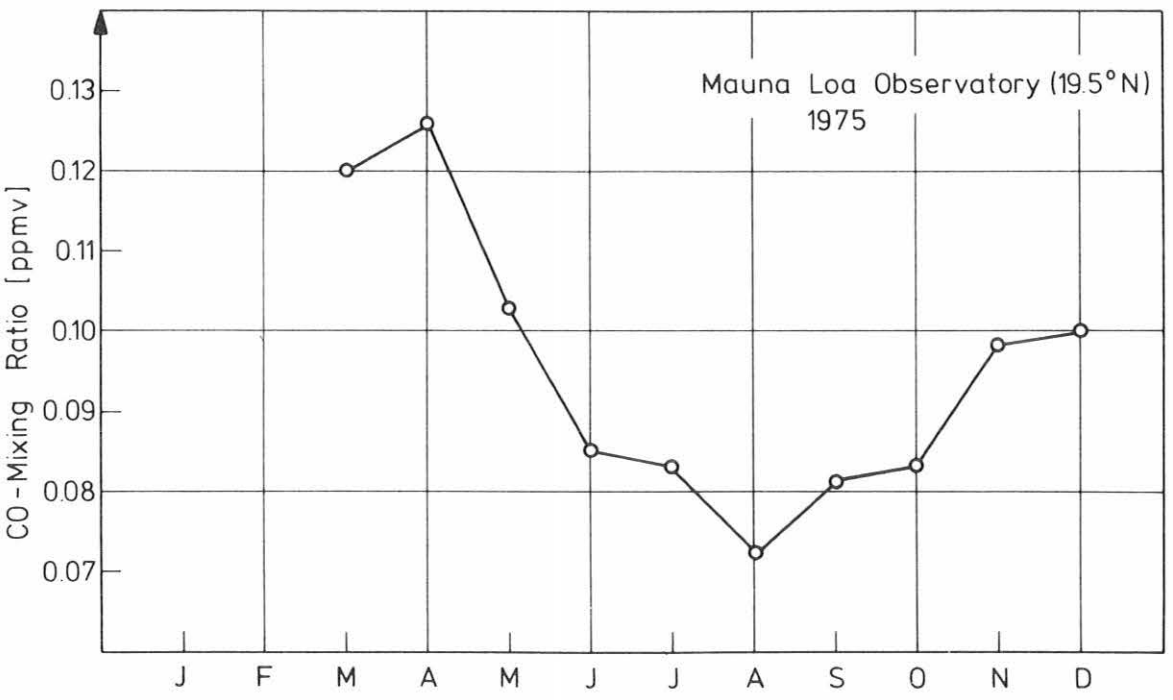


Figure 65. Monthly variation of carbon monoxide mixing ratios.

5.2 Barrow Observatory

5.2.1 Stratospheric Nitrogen Dioxide (NO_2) Measurements

John F. Noxon, Principal Investigator
Aeronomy Laboratory, NOAA

A prototype spectrometer to monitor stratospheric NO_2 using ground-based optical methods was installed at Barrow in early August 1975 and reinstalled in November. The instrument views out a double-pane window onto a mirror and into the zenith sky. By measuring certain absorption features of NO_2 in the twilight sky, the instrument can automatically determine the stratospheric NO_2 abundance. A large amount of good data has been accumulated and is now undergoing analysis. It is clear that the instrument functions as expected and that a continuous series of daily measurements is now in hand.

The present instrument is due to be replaced in the summer of 1976 by a fully automated version that will be located on the roof of the building with the recording system located inside. The new instrument will track the Sun and measure the direct transmission in the NO_2 absorption bands and automatically determine the tropospheric and stratospheric NO_2 concentration.

Similar instruments will be developed for use at the three other GMCC observatories. Eventually, NO_2 instruments will be installed at all the GMCC observatories.

5.2.2 Smithsonian Solar Radiation Program

Bernard Goldberg, Principal Investigator
Smithsonian Radiation Biology Laboratory

The Smithsonian Radiation Biology Laboratory has solar radiation monitoring equipment in Barrow, Alaska, continuously recording the spectral distribution of natural daylight. There are two types of detectors in use at this location: Eppley precision pyranometers and a photoelectric detector which is used for monitoring the UVB spectrum. The six pyranometers use Schott colored domes to produce 100-nm to 2800-nm spectral data. The photoelectric detector is used with eight pairs of interference filters to monitor the UVB in 5-nm bands from 285-nm to 320-nm.

The information from these detectors has been gathered by a digital acquisition system on punched paper tape. Because the old acquisition system failed in September 1975 after approximately four years of continuous use, the Radiation Biology Laboratory modified a commercial system to replace it. The new modified system will be put into operation in March 1976. The values of the daily totals of the spectral data collected from the pyranometers have been published by the Smithsonian Institution, and are available for the years 1971-1973. The data since 1973 are being prepared for publication. An analysis of the data will be published in *Solar Energy* sometime in 1976.

5.3 South Pole Observatory

5.3.1 Atmospheric Electric Measurements

William Cobb, Principal Investigator
Atmospheric Physics and Chemistry Laboratory, NOAA

A 5-year program of atmospheric electric measurements is now in its fourth year at the Amundsen-Scott South Pole Station. After the opening of the new station in January, electrical sensors were moved from the old VLF site to the new Clean Air Facility where the air-Earth conduction current density and the atmospheric potential gradient are continuously recorded. The potential gradient sensor, an induction-type field mill designed to withstand low temperatures, is mounted on a post about 1 m above the snow surface. The air-Earth current sensor consists of a passive antenna about 12 m long, suspended 1 m above the snow. Control panels and a strip chart recorder are located in the "clean-air" building. To supplement the surface measurements, modified radiosondes, designed to measure the air-Earth current density to as high as 35 km, were released biweekly throughout the year by the National Weather Service. Major objectives of the program are to establish an environmental benchmark of electrical parameters sensitive to aerosol pollution, and also to investigate those processes that may control or influence the "global circuit". The global circuit is a term used to describe the flow of electrical current between the Earth and the ionosphere, which, according to the most widely accepted hypothesis, is maintained by the ever-present global thunderstorm activity. Confirmation of this hypothesis has been difficult because at most measuring sites the global effects are masked by local influences resulting from man-made pollution, radioactive soils, 24-hour diurnal cycles, etc., effects that are absent on the polar plateau.

The surface measurements of the potential gradient and the air-Earth current density at the South Pole are providing the best evidence yet obtained in support of the global thunderstorm hypothesis. Thus in Fig. 66, which shows the mean diurnal variation of the potential gradient at the Pole, the peak at 1500-1900Z occurs when the sun is passing over Africa and South America where thunderstorm activity is the greatest. A secondary peak at 0700Z occurs when the sun passes over Asia, and the minimum potential gradient occurs when the sun is over the Pacific Ocean and global thunderstorm activity is at its lowest level. We are, in effect then, monitoring changes in the global thunderstorm activity from the South Pole.

With respect to aerosol pollution, the measurements must be considered over long time spans where the baselines established now may be checked at 5 to 10 year intervals in the future to look for possible secular changes. It is especially important to establish an index for stratospheric conditions where particle residence times are much longer than in the troposphere. Frequent radiosonde balloon flights are being made of the air-Earth current density to establish such an index for the stratosphere. The presence of only 5 to 10 aerosol particles per m^3 will significantly reduce the air-Earth current measurement in the stratosphere. Classical theory claims that the air-Earth current in fair weather is constant with altitude. However, balloon measurements at the Pole (Fig. 67) have shown that this is frequently

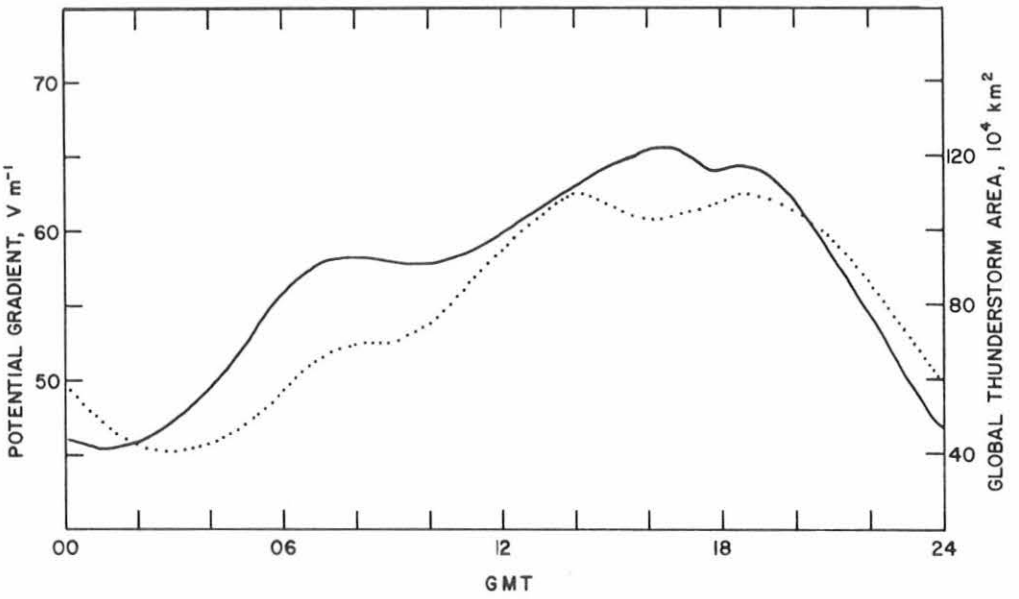


Figure 66. Mean diurnal variation of the potential gradient (solid line) at the South Pole and the global thunderstorm area (Whipple and Scrase, 1936).

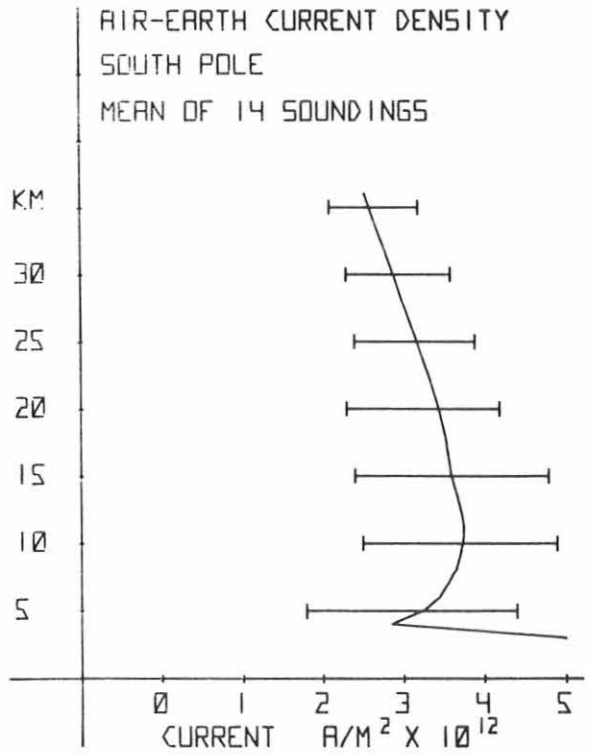


Figure 67. Average air-earth conduction current density from balloon measurements at the South Pole.

not true and that the current is more likely to peak at about 11 km and decrease slowly thereafter. The balloon flights analyzed to date suggest that factors in addition to the global thunderstorm activity influence the stratospheric air-Earth current at the Pole. One possibility is the presence of enhanced particulate concentrations extending well into the upper stratosphere.

The South Pole atmospheric electric program has been supported by the National Science Foundation (Grant OPP74-19486), the National Weather Service, and the Atmospheric Physics and Chemistry Laboratory of NOAA, as well as by the GMCC program.

5.4 Samoa Observatory

5.4.1 Trace Elements in the Marine Atmosphere

Robert A. Duce, Principal Investigator
Graduate School of Oceanography
University of Rhode Island

There has been increasing concern in the last few years over the evidence that measurable quantities of lead and perhaps other trace metals, DDT, PCB, petroleum hydrocarbons and other organic substances are transported to the open ocean by the atmosphere, either as particles or in the gas phase (Study of Critical Environmental Problems, 1970; FAO Fisheries Reports, 1971). Although this long-range transport of atmospheric pollutants is generally accepted, there have been few concerted efforts to relate atmospherically transported pollutants, particularly trace metals and chlorinated hydrocarbons, to the general problem of open ocean pollution until the initiation of our NSF-supported program in 1972. Before this program began there was virtually no information on the mean concentration of these substances in the atmosphere in the westerlies over the North Atlantic, where pollutant transport from the heavily industrialized North American continent would be a maximum. Previous work in this area had been limited to a small number of samples collected from ships without systematic control of geographic location and without consideration of rapidly changing meteorological conditions. The flux of most of these atmospheric pollutants to the ocean was completely unknown as was the rate of their re-introduction into the atmosphere by spray and bubble breaking. Very little is still known concerning the mechanisms of deposition of these pollutants into the ocean from the atmosphere.

The most practical way to obtain reasonable values for atmospheric concentrations and fluxes of pollutants out over the ocean is to have a stationary sampling site in operation over a relatively extended period of time. In this way meaningful information on the "climatological mean" concentration of the substance of interest can be obtained. For this reason we have chosen stationary tower sites in mid-ocean locations for our studies of the chemistry of the marine atmosphere.

Our initial tower site was on the windward coast of Oahu, Hawaii, and was utilized from 1968 to 1970 and in 1975. This mid-Pacific site is in the northeast trades and is an ideal location for evaluating long-range transport of substances from North America to the tropical North Pacific. Our second tower site was on Bermuda and was utilized from 1972 to 75. This site is approximately 1100 km off the east coast of the United States, primarily in the westerlies, but often under the influence of the North Atlantic trade wind regime in the summer, with near surface air flow from the eastern Atlantic. The primary value of this site was thus its location in an area where there were clear shifts from synoptic patterns with a reasonably close major air pollution source to synoptic patterns with wind trajectories passing only over the open sea for thousands of kilometers.

Over 90% of the atmospheric pollutants are injected into the Northern Hemisphere. With the relatively short residence times of atmospheric particles (days to 1-2 weeks) and the relatively long tropospheric mixing times between the Northern and the Southern Hemisphere, significant differences should be observed for anthropogenic source substances present on atmospheric particles at remote areas in the two hemispheres. To date, there is no information on trace metal distributions in remote marine Southern Hemisphere locations. For this reason we constructed a walk-up sampling tower in October 1975 at Cape Matatula adjacent to the new NOAA GMCC Observatory (Fig. 68).

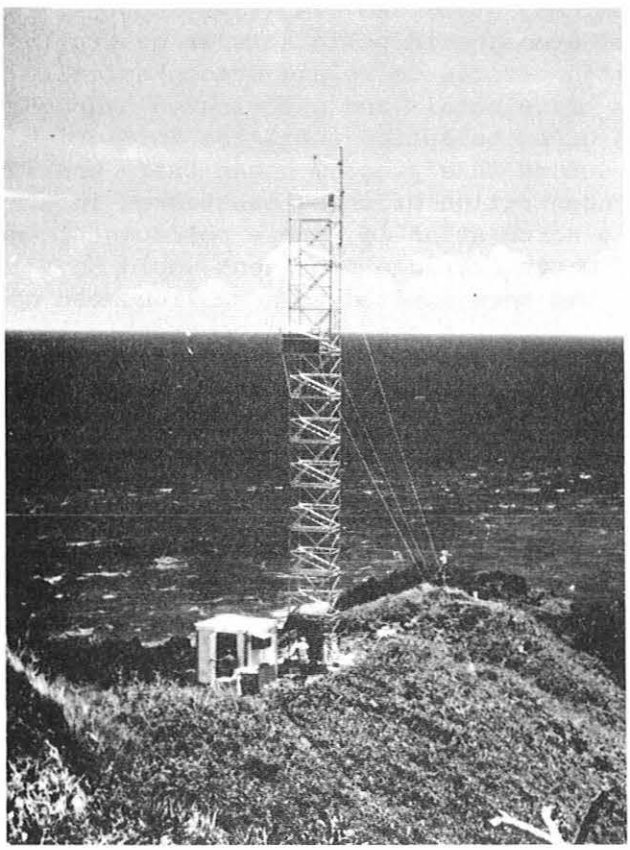


Figure 68. University of Rhode Island sampling tower at Cape Matatula, American Samoa.

The base of the Samoa tower is located about 30 m above sea level, near the edge of a rather precipitous cliff on the southeast side of Cape Matatula. It is thus ideally located, relative to the prevailing southeasterly trades, to avoid local contamination, both from man-made sources and from natural erosion products and surf spray. The tower itself is 20 m high, with the tower top approximately 50 m above sea level. Smoke flare tests indicate that surface air blowing up the face of the cliff does not reach more than halfway up the tower before passing by the tower. Samples collected on the top of the tower thus receive no local contamination generated by air blowing up the cliff.

In any atmospheric collection program of this type it is critical that as much as possible be known about the past history of the air being sampled. The pumps used to collect the samples on the tower are controlled by wind direction through a directional air sampler control. This directional control allows the pumps to be operated automatically when the wind is blowing from some predetermined sector of the compass, thus avoiding the local contamination that can occur when the wind is off the land. Many filter holders have a door that automatically closes over the filter when the pump is shut down because of out-of-sector winds. This prevents filter contamination from non-marine air when the pumps are not operating.

An Environment/One Model Rich 100 recording condensation nucleus counter (Environment/One Corp., Schenectady, New York) is also located near the top of the tower. Since local pollution particles are excellent condensation nuclei (CN), short term rapid variations in CN counts can indicate air mass changes and/or possible local contamination of samples. The CN counter is integrated into the directional air sampling control system so that collection occurs only when the wind is off the ocean and when CN counts are near background for marine air, 300-400 per cm^3. This is an added safeguard against collection of local pollution. Recorders for wind speed and direction, CN counts, rainfall, and pump operating times are housed in the small air-conditioned building near the base of the tower.

Atmospheric collection equipment (i.e. filter holders, impactors, etc.) is located on the top level of the tower. Bulk particulate samples for trace metal analysis are collected on double Whatman 41 filters (20 x 25 cm) or Nuclepore filters mounted in all plastic filter holders and rain shelters. Particle size separated samples are collected using a Sierra Hi-Volume cascade impactor. The particles for trace metal analysis are deposited on Whatman-41 filter paper on each impactor stage. The fifth stage is followed by a final filtration through Whatman-41 filters. Particles to be analyzed by electron microscope and microprobe are collected on 47-mm 0.4-μm Nuclepore filters. Bulk particles to be analyzed for total organic carbon are collected on pre-combusted Gelman Type-A glass fiber filters. High-volume impactor samples for organic carbon analysis also utilize glass fiber filters. Air sampling pumps are separated from the filters and impactors by 8 meters of 7.6-cm diameter fiber glass tubing, the pumps being located at a lower level of the tower. This avoids contamination from the pumps themselves (Hoffman and Duce, 1971).

Samples for the vapor as well as the particulate phase will be collected for Hg and As. The Hg collection system and analysis technique to be employed is a modification of the design now used by the regional EPA laboratory in Needham, Massachusetts, to monitor Hg in the atmosphere (Spittler et al., 1976). We will use a gold amalgamation trapping stage. Braman and Johnson (1974) found that gold effectively amalgamates and traps all the major atmospheric species of Hg: elemental Hg, inorganic Hg (II) compounds, methyl Hg (II) type compounds, and dimethyl Hg. A column packed with gilded glass beads will provide an efficient collector at much less expense than a corresponding volume of gold beads.

Techniques have been developed for the separation and collection of gaseous and particulate As in the atmosphere. After removal of the particles by a Nuclepore filter, the gas phase is collected on a series of Whatman-41 filters impregnated with an aqueous solution of 10% glycerol and 10% polyethylenimine, a strong organic base. This system has been tested in the laboratory and in the field and is quite efficient for such species as As_4O_6, the most volatile As compound that is stable in air, and hydroxydimethylarsenic acid.

Samples will be collected for PCB and DDT by using the technique of Bidleman and Olney (1974), which involves the passage of large volumes of air first through a precleaned glass fiber filter and then through a series of porous polyurethane plugs for vapor phase collection.

An initial test phase of the entire sampling system will run for 6 weeks in January-February 1976. Two 6-month intensive sampling periods are now planned in Samoa from June to November 1976 and May to October 1977.

6. DATA MANAGEMENT

This section documents changes in the various systems and techniques used to acquire and reduce GMCC baseline data. Information on data archiving is also presented.

6.1 Data Acquisition

6.1.1 Standardization of Hardware

The major task during 1975 was to standardize the computer hardware at each station in order to avoid the complexity imposed by operating individualized hardware. The largest number of modifications required was at South Pole. There a new display clock and its accompanying interface were installed. Also a drawer that allows direct signal access through the use of terminal strips replaced a matrix board configuration. In addition, the core size was increased to 16k words, so that the software at Mauna Loa and Boulder could be used at the other stations as well. These changes were implemented in December, bringing the ICDAS at the South Pole into complete conformity with the other stations.

6.1.2 Software Modifications

To facilitate the reduction and subsequent processing of the data tapes from the stations, the content and dimension of the data arrays was standardized with the use of the new executive program called Basic Operating System Software (BOSS) 75170. BOSS was installed at the Mauna Loa Observatory during the summer, at Barrow in October, and at the South Pole in December. Any future modifications to this software will not change the operating procedures, content, or structure of the data arrays to any significant degree.

6.1.3 Installations

BARROW

Shortly after the first of the year, the hardware components of ICDAS data system for the Barrow station were assembled, tested and evaluated (Fig. 69). The system was installed at the station during the first two weeks in April with only minor problems. Data acquisition commenced April 15. The flow of data from Barrow suffered only minor interruptions until a major power outage occurred in mid-November. During this period of low voltage, some components were damaged. The data system remained inoperative until after the first of the year, because of the complexity of the damage.

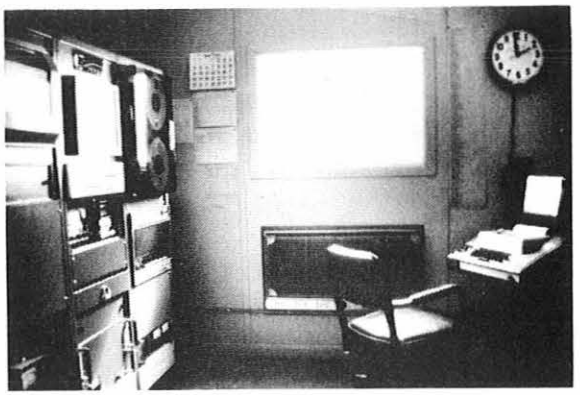


Figure 69. The ICDAS installation at the GMCC station, Barrow, Alaska.

BOULDER

By mid-year, the main components of the data reduction facility at Boulder had been assembled and tested. The facility consists of a magnetic tape drive, minicomputer, and teletype like those installed at each station, and a dual disc system, a graphics display, and a high-speed reader and punch (Fig. 70). This facility will be used to read and check the data tapes from the observatories. If parity errors are present, a new clean tape will be prepared for further analysis at the ERL computer facility.

SAMOA

With the completion of the data reduction facility, work began on testing the components of the ICDAS for the observatory at American Samoa. All the latest modifications were included and the system was operating in Boulder by mid-September. Tests continued until mid-November when the equipment was prepared for shipment to Samoa. The data system was installed without difficulty in January 1976. The installation in Samoa differs from those at the other GMCC observatories in that the digital components run on power

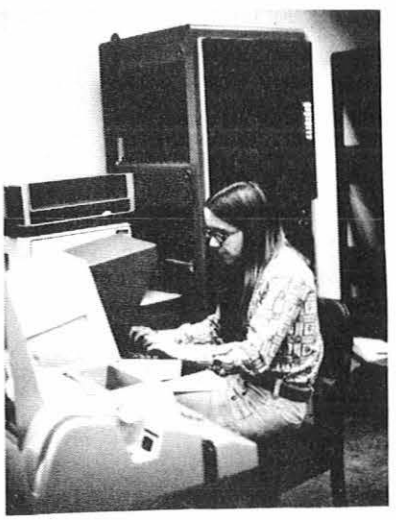


Figure 70. The data reduction facility in operation at Boulder, Colorado.

from an uninterruptable power supply (UPS). Through the use of this device, it is possible to keep the computer and tape drive on line while the power shifts from island power to emergency generator power and back again. If this method of bridging short (<5 min) power outages proves successful, uninterruptable power supplies may be installed in Barrow and at the South Pole next year.

6.2 Data Reduction

In October, a new group was formed within GMCC to manage the flow of data from the observatories to the national archive, the World Data Center in Asheville, N.C. The group's main functions are named in its title, the Acquisition and Data Management Group, or A&DM. In the latter half of the year, emphasis was placed on developing programs to read and display data for quality evaluation. This resulted in a three-step evaluation routine. In the first step only the quality, identification, and continuity of the magnetic tape itself are checked. In the second step, the performance of the BOSS in terms of calibration and missing data is checked. And in the last step the measurements are displayed in tabular or graphic form for evaluation by the responsible scientists. This sequence of evaluation will probably undergo considerable change as new problems are uncovered.

6.3 Data Archiving

6.3.1 Total Ozone

During 1975, total ozone data for the period January 1974 through June 1975 were sent to the Atmospheric Environment Service of Canada (Downsville, Ontario). This agency publishes ozone data for the World Meteorological Organization (WMO). The observations were from Bismarck, N. Dak.; Caribou, Maine; Green Bay, Wis.; Tallahassee, Fla.; Mauna Loa Observatory, Hawaii; Wallops Island, Va.; Nashville, Tenn.; Boulder, Colo.; White Sands, N. Mex.; Huancayo, Peru. Data from the winter months of January and February are missing for Barrow, Alaska.

6.3.2 Surface Ozone

Measurements of the concentration of ozone at the surface are also published by the Atmospheric Environmental Service of Canada. During 1975, data from the Barrow Observatory, for the period March 1973 to July 1975, and from the Mauna Loa Observatory for August 1973 to July 1975 were archived (see Section 4.1.3). In both cases a device employing an electrochemical concentration cell was used to measure ozone. The data for the period March 1974 to November 1974 from the South Pole station were also archived. Measurements at the South Pole were made with an instrument using a chemiluminescent determination of ozone. The data are one-hourly average concentrations.

6.3.3 Solar Radiation

Daily integral values of the horizontal incident radiation measured at the Mauna Loa Observatory were sent to the World Data Center A in Asheville, N.C., for the period January through August 1975.

7. RESEARCH CONTRACTS

This section provides a brief review of each research contract or grant funded by GMCC during 1975.

7.1 Center for the Environment and Man

Title: A Study of Transmission of Solar Radiation by the Atmosphere
Principal Investigator: G. D. Robinson
Period of Study: June 1, 1975 to January 31, 1976
NOAA Contract No: 03-5-022-79

The work proposed falls into three categories:

1. The Relevance of Solar Radiation Measurements in Monitoring for Climatic Change.

The final result will be a critical essay surveying the purpose, potential, and achievement to date of the measurements now being made at Mauna Loa Observatory. It will be produced in close consultation with the staff of Air Resources Laboratory, and its intention will be to help them to decide what (if any) changes should now be made in the instrumentation, the mode of its use, and the reduction and retention of data.

Attenuation by absorption and scattering by gases and particles will be considered, with regard to both the idealized performance of the current equipment and its actual performance in the field. The work will include an analysis of the idealized and likely responses of the equipment to hypothetical perturbations; the analysis will use simple single-scatter approximations (which can be shown to be sufficiently accurate for the purpose). The following matters will also be considered:

- The nature of the requirement for continuity—continuous vs. expedition-type operation at remote stations.
- Filter vs. spectrometer for the required spectral separation.
- The case for less remote stations with higher than network standards of accuracy.

2. A Continuation of the Examination of the Mauna Loa Results, With Particular Reference to Instrument Performance.

In CEM Report No. 4149-507 (NOAA Contract No. 03-3-022-157) an analysis was made of certain data averaged over 10 days in 1974 This showed that certain components of the Mauna Loa equipment were performing at the expected, geophysically useful, level of accuracy. It is proposed to continue this analysis to show the day-to-day variance, and to examine the performance

of some other components that do not on first examination appear to reach the required standard.

In addition, one year's tabulations of the Mauna Loa radiation record, arranged according to solar angle, will be examined. Occasions when the record is sufficiently complete and without obvious error will be isolated, and a selection will be examined by the methods used in the work performed under Contract No. 03-3-22-157.

Any repeated anomalies of glass filter performance (i.e., apparent systematic deviation from accepted spectral properties) will be isolated. Alternative explanations of the anomalies, related to atmospheric attenuation or the assumed extra-terrestrial spectrum, will be examined.

3. Consultation

The services of Dr. G. D Robinson will be available for consultation with staff members of ARL at their request, within the proposed effort.

7.2 Geophysical Institute, University of Alaska

Title: An Investigation of Aerosol Characteristics at Mauna Loa Observatory
Principal Investigator: Glenn E. Shaw
Period of Study: October 1, 1974 to February 1, 1975
NOAA Contract No: 05-5-222-310

The work proposed will accumulate additional information on the radiation field at Mauna Loa by measuring the following parameters during clear weather periods:

a) Atmospheric transmission (optical depth) at six narrow wavelength intervals distributed over the visible spectrum.

b) The distribution and magnitude of diffuse sky intensity (in absolute units) over the entire celestial hemisphere in six narrow wavelength regions.

The above parameters will be derived from measurements made with special interference-filter photometers that have been developed over the past several years. The diffuse radiation field at small angular distances from the sun will be evaluated with a photoelectric coronometer.

Interpretation and analysis will proceed as follows:

WAVELENGTH DEPENDENCE OF AEROSOL OPTICAL DEPTH

The optical depths at each filter wavelength due to scattering and absorption by atmospheric aerosols will be obtained from sun photometry

measurements. A smooth curve drawn through the data points will estimate the shape of aerosol optical depth curve with wavelength.

INTERCOMPARISON WITH EPPLEY NORMAL INCIDENCE PYRHELIOMETER

Based on the inferred aerosol extinction curve (as derived in "a.") and using published values of the solar flux, the incoming direct solar radiation, wavelength by wavelength, will be calculated over the visible spectrum. The results will be combined with published curves for the Schott Standard glass filters and then compared with the stations normal-incidence pyrheliometer data. Water vapor absorption effects will be minimized by subtracting readings taken through two different cutoff filters to derive the incoming solar flux between wavelength regions in the visible region. In addition, aerosol optical depths derived with our photometer, and with the new multi-wavelength normal incidence pyrheliometer at Mauna Loa, will be compared to establish representative errors that may arise when two entirely different instruments are used to derive atmospheric transmission.

EVALUATION OF AEROSOL SCATTERING PHASE FUNCTION

The form of the aerosol scattering phase function will be estimated by employing an analysis of the distribution of sky intensity in the solar almucantar.

EVALUATION OF MULTI-WAVELENGTH DIFFUSE FLUX

The observed sky intensity will be numerically integrated over solid hemispheric angle to obtain numerical estimates of the downwelling diffuse fluxes at the filter wavelengths; these will be compared with calculated values that would result from a pure Rayleigh-scattering atmosphere.

CALCULATIONS OF BACKSCATTERED ENERGY AND ABSORPTION

The method described by Robinson (1974) will be utilized to evaluate the ratio of backscattered-to-absorbed energy fluxes by the Earth-atmosphere system at the filter wavelengths.

7.3 Institute for Arctic and Alpine Research (INSTAAR)

Title: Background Gas Sampling at Niwot Ridge, Colorado
Principal Investigator: John Clark
Period of Study: December 15, 1975 to December 14, 1976.
NOAA Contract No: 01-6-022-12770

The proposed work will continue carbon dioxide flask sampling at Saddle Point, West Knoll on Niwot Ridge 23 miles west of Boulder, Colorado. These measurements were previously made during the years 1966 through the beginning of 1974. In addition to paired carbon dioxide flask sampling, one pair of flasks will be exposed for fluorocarbon measurements. Sampling will be made on a weekly basis. However, actual sampling frequency may vary to take

advantage of optimum sampling conditions or because of delays caused by severe weather. In most cases, sampling will be made at least once every 10 days over a 1-year period.

Supplementary meteorological measurements will be made including wind speed and direction, cloud cover, visibility, present precipitation, and temperature.

Exposed flasks will be returned to GMCC Boulder for analysis and data reduction.

7.4 Cornell University

Title: Calibration of Collection Procedures for Determination of Precipitation Chemistry
Principal Investigator: Gene E. Likens
Period of Study: July 16, 1975 to July 15, 1976
NOAA Contract No. 04-5-022-24

GMCC provided partial funding to continue Cornell's intercomparison study of precipitation collectors and precipitation analysis techniques as initiated under the 1974 ERL Grant No. 04-4-022-31.

A summary of the work performed under this contract is contained in Section 4.6.1.

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10. GEOPHYSICAL MONITORING STAFF

10.1 Director's Office

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Donald H. Pack, 1971-July, 1975
Kirby J. Hanson, 1975-Present

10.1.2 Director's Office

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Milton S. Johnson, Electronic Technician

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10.5 Mauna Loa

10.5.1 Directors of Mauna Loa Observatory

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

10.5.2 Mauna Loa Observatory Staff

*Ronald Fegley, Director
*Barry A. Bodhaine, Research Physicist
John F. S. Chin, Physicist
Howard Ellis, Physicist
*Bernard Mendonca, Research Meteorologist
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*Steven Kott, Lt. JG, NOAA
George Engeman, Electronic Technician

10.8 Samoa

*Vernon T. Rumble, Station Chief
*Donald W. Nelson, Physical Scientist

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*Contributors to the Summary Report

APPENDIX

Mauna Loa Observatory Pyranometer History

Measurements of horizontal incidence of hemispheric irradiance measurements at Mauna Loa Observatory began in October 1957 and have continued to the present. Eppley pyranometers were used (bulb type) until October 1975. Eppley Mod II pyranometers have been used since. Table A.1 lists all the instruments.

Table A.1 Pyranometers Used for Solar Radiation Records at Mauna Loa Observatory, Hawaii

Instrument No.	Type	Date On	Date Off
3201	NWS bulb	Jan. 1, 1958	Mar. 4, 1959
2065	NWS bulb	Mar. 5, 1959	June 2, 1959
2597	NWS bulb	June 3, 1959	July 1, 1960
3201	NWS bulb	July 2, 1960	Feb. 25, 1961
3963	NWS bulb	Mar. 4, 1961	Oct. 4, 1961
3201	NWS bulb	Oct. 5, 1961	Oct. 9, 1961
4215	NWS bulb	Oct. 10, 1961	July 24, 1962
3201	NWS bulb	July 28, 1962	Dec. 15, 1962
1825	NWS bulb	Dec. 15, 1962	Jan. 2, 1964
5269	NWS bulb	Jan. 3, 1964	Jan. 14, 1964
1825	NWS bulb	Jan. 15, 1964	Feb. 3, 1965
1833	NWS bulb	Feb. 4, 1965	June 29, 1974
1825	NWS bulb	Jan. 30, 1974	Sep. 29, 1975
12616	Eppley Mod II	Sep. 30, 1975	Present

Table A.2 contains the calibration records that are available for these pyranometers. Of the NWS bulb types used, all sensors except instrument #2065 were coated with Parson's black. In the calibration procedure these pyranometers were compared with a lamp black coated standard under artificially generated incident light in an enclosed sphere. The temperature of calibration was 26.7°C. Later some of the Parsons black coated pyranometers were compared with a Parsons black coated standard in a similar manner. The calibration constants assigned to the working pyranometers were transferred from the lamp-black coated standard. The difference between sensitivity of the lamp-black coated instrument and the Parson's-black coated instrument is

Table A.2 Mauna Loa Observatory Pyranometer Calibration History

Ser. No.	Instr. Type	Initial Cal.	Date	Terminal Cal.	Date
3201	NWS bulb (P)	2.32 (L)	5.57	2.06 (L)	7/73
2065	NWS bulb (L)	2.02 (L)	1/58	No Records	
2597	NWS bulb (P)	2.39 (L)	1/59	No Records	
3963	NWS bulb (P)	No Records (7.10)		No Records	
4215	NWS bulb (P)	No Records (7.05)		No Records	
5269	NWS bulb (P)	2.30 (L)	9/63	2.04 (L) 2.21 (P) 2.35 (L)	7/73 7/73 9/67
1825	NWS bulb (P)	2.43 (L)	9/62	2.23 (L) 2.43 (P)	12/75 12/75
1833	NWS bulb (P)	1.95 (L)	8/58	1.52 (L) 1.66 (P)	12/75 12/75
12616	Eppley Mod II	5.54	?	In Use	

(P) = Parsons-black coated sensor
(L) = Lamp-black coated sensor
In the calibration columns these letters indicate the type of standard instrument used in the calibration.
Calibration constants are expressed in mv/langley
The two numbers in parentheses in the calibration columns are the calibration constants stamped on the pyranometer.

the "cross match factor". After numerous comparisons an average difference of 7% ± 2% has been assigned as the cross match factor. The effect of the cross match factor is to decrease the values of the measured irradiance by 7% ± 2% on the average if the comparison using the Parson's black standard is considered more representative. The Mauna Loa Observatory data have not been adjusted for the cross match factor. The crossmatch factor is not applicable to the Eppley Mod II pyranometer.

Table A.2 also shows a decay in instrument sensitivity with time for the Parson's black coated pyranometers. This decay is expressed by the difference in the instrument sensitivity between the initial calibration and the terminal calibration. The rate of decay is unknown. No correction has been applied to the data to adjust for this decay in sensitivity.

Besides being intercompared against a standard (which assigned the instrument sensitivity) some pyranometers were compared with other pyranometers on site at Mauna Loa Observatory under ambient conditions and clear skies. Table A.3 lists these intercomparisons. Daily totals of the

Table A.3. Pyranometer Intercomparisons at Mauna Loa Observatory, Hawaii

Period of Comparison	X Greater Total (Instrument)	Calibration Constant	Y Lower Total (Instrument)	Calibration Constant	$\frac{X}{Y}$
3/ 5/59 - 5/13/59	2065	2.02	3201	2.32	1.04
6/ 5/59 - 6/24/59	2597	2.39	3201	2.32	1.08
7/ 4/59 - 7/29/59	2597	2.39	3201	2.32	1.08
8/ 1/59 - 8/11/59	2597	2.39	3201	2.32	1.09
9/10/59 - 9/23/59	2597	2.39	3201	2.32	1.09
10/ 8/59 - 10/23/59	2597	2.39	3201	2.32	1.07
11/16/59 - 11/25/59	2597	2.39	3201	2.32	1.08
12/ 3/59 - 12/31/59	2597	2.39	3201	2.32	1.08
1/ 5/60 - 1/25/60	2597	2.39	3201	2.32	1.06
4/23/60 - 4/24/60	2597	2.39	3201	2.32	1.09
5/ 5/60 - 5/30/60	2597	2.39	3201	2.32	1.07
6/12/60	2597	2.39	3201	2.32	1.10
7/ 3/60 - 9/ 2/60	2597	2.39	3201	2.32	1.11
4/12/61 - 5/ 8/61	3963	7.10	3201	2.32	1.02
8/ 2/61 - 8/ 3/61	3963	7.10	3201	2.32	1.02
11/17/61 - 11/27/61	4215	7.05	3201	2.32	1.02
1/ 1/62 - 1/29/62	4215	7.05	3201	2.32	1.03
2/ 3/62 - 2/22/62	4215	7.05	3201	2.32	1.02
3/ 2/62 - 3/31/62	4215	7.05	3201	2.32	1.04
4/ 1/62 - 4/29/62	4215	7.05	3201	2.32	1.06
5/ 4/62 - 5/23/62	4215	7.05	3201	2.32	1.07
6/ 4/62 - 6/24/62	4215	7.05	3201	2.32	1.08
12/ 8/62 - 12/16/62	1825	2.43	3201	2.32	1.14
10/16/63 - 10/31/63	1833	1.95	1825	2.43	1.01
11/ 1/63 - 11/30/63	1833	1.95	1825	2.43	1.02
12/ 1/63 - 12/17/63	1833	1.95	1825	2.43	1.02
12/18/63 - 1/ 2/64	1825	2.43	5269	2.30	1.02
1/ 3/64 - 1/10/64	1833	1.95	5269	2.30	1.04
2/ 4/65 - 2/22/65	1833	1.95	1825	2.43	1.04
7/ 1/74 - 7/ 8/74	12616	5.54	12617	5.65	1.001
7/ 1/74 - 7/ 8/74	1825	2.43	12617	5.65	1.051
8/ 8/75 - 8/25/75	1825	2.43	12616	5.54	1.0276
3/30/76 - 4/16/76	12616	5.54	12617	5.65	1.006

Note: Ratios ($\frac{X}{Y}$) are of Daily Totals.

irradiance measured were used to obtain ratios between the two pyranometers. The differences between the two pyranometers changed with solar angle (time of day). Figure A.1 presents two examples of this. Such variations in the differences between two pyranometers with the time of day (solar angle) were common.

The response of the pyranometers at different ambient temperatures is another correction factor that has not been applied to the data collected. This temperature correction is the measured difference in instrument response at the ambient temperature of calibration (26.7°C) as compared with the response at the ambient temperature of operation out in the field. For the conditions at Mauna Loa Observatory, the ambient working temperature averages 7.2°C with a minimum of 0.0°C and a maximum of 14°C. Of the pyranometers used, those of the Eppley bulb type are the most temperature-sensitive. Tests at the NWS laboratories have shown that the average correction is 0.144%/°C change in temperature. The correction is such that the irradiance measured by the bulb pyranometers is high if the ambient temperature is below 26.7°C. For Mauna Loa Observatory the average correction would be ∿-2.8% with a maximum of ∿-3.8% and a minimum of ∿-1.8%.

The final adjustment to the data obtained at Mauna Loa Observatory involves a resolution of the scales used to a common scale based on an absolute measurement of solar energy. The NWS Eppley bulb pyranometer measurements of solar radiation at Mauna Loa Observatory are based on the Smithsonian scale of 1913 with the IPS 1956 correction. The Eppley Mod II pyranometer measurements of solar radiation at Mauna Loa Observatory are based on the Angstrom standard of 1956. The difference between these two scales is ∿3% with the scale used by the NWS Eppley bulb pyranometers being higher. The anticipated WMO primary standard scale, which is based on absolute measurements of solar radiation using the PACRAD 3 instrument, is ∿0.6% below the scale used by the NWS Eppley bulb pyranometers and ∿2.4% higher than the scale used by the Eppley Mod II pyranometer. Therefore adjustments of ∿-0.6% and ∿+2.4% can be applied to the Eppley bulb pyranometer and Eppley Mod II pyranometer measurements of solar radiation respectively, to make them comparable with the anticipated WMO standard and with each other.

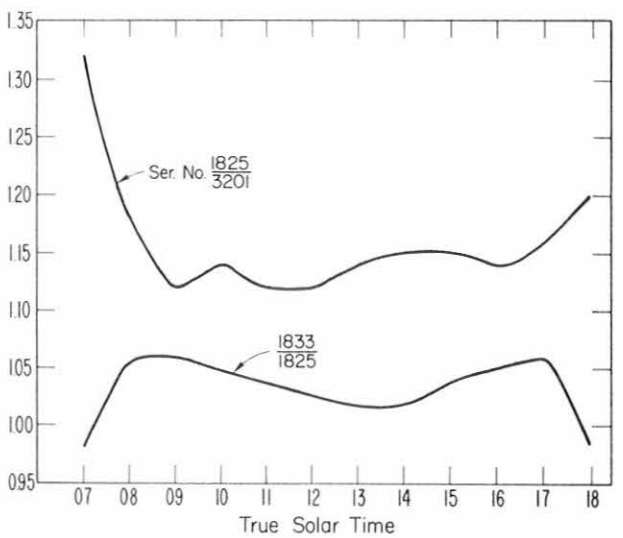

Figure A.1. Hourly ratios for pyranometer intercomparisons, Mauna Loa Observatory, Hawaii.

Table A.4 summarizes the corrections that can be applied to the measurements of solar radiation made at Mauna Loa Observatory. When there are no data available a "?" is entered or the average values are entered when they are applicable.

Table A.4 Summary of Corrections to Pyranometer Measurements of Solar Radiation Made at Mauna Loa Observatory

Instr. Ser. No.	Crossmatch Factor	Average Temperature Correction	Sensitivity Decay	Scale Correction	Net Correction
3201					
Start 5/57	-7.0	-2.8	0.0	-0.6	-10.4
End 7/73	-7.0	-2.8	12.6	-0.6	+ 2.2
2065					
Start 1/58	none	-2.8	?	-0.6	- 3.4
End ?	none	-2.8	?	-0.6	- 3.4
2597					
Start 1/59	-7.0	-2.8	?	-0.6	-10.4
End ?	-7.0	-2.8	?	-0.6	-10.4
3963					
Start ?	-7.0	-2.8	?	-0.6	-10.4
End ?	-7.0	-2.8	?	-0.6	-10.4
4215					
Start ?	-7.0	-2.8	?	-0.6	-10.4
End ?	-7.0	-2.8	?	-0.6	-10.4
5269					
Start 9/63	-7.0	-2.8	0.0	-0.6	-10.4
End 7/73	-7.7	-2.8	+12.7	-0.6	+ 1.6
1825					
Start 9/62	-7.0	-2.8	0.0	-0.6	-10.4
End 12/75	-8.2	-2.8	+ 9.0	-0.6	- 2.6
1833					
Start 8/58	-7.0	-2.8	0.0	-0.6	-10.4
End 12/75	-8.4	-2.8	+28.3	-0.6	+16.5
12616					
Start ?	0.0	0.0	0.0	+2.4	+ 2.4

Note: Corrections are in Percent of the Original Data.

U. S. GOVERNMENT PRINTING OFFICE 1976 - 677-347/129