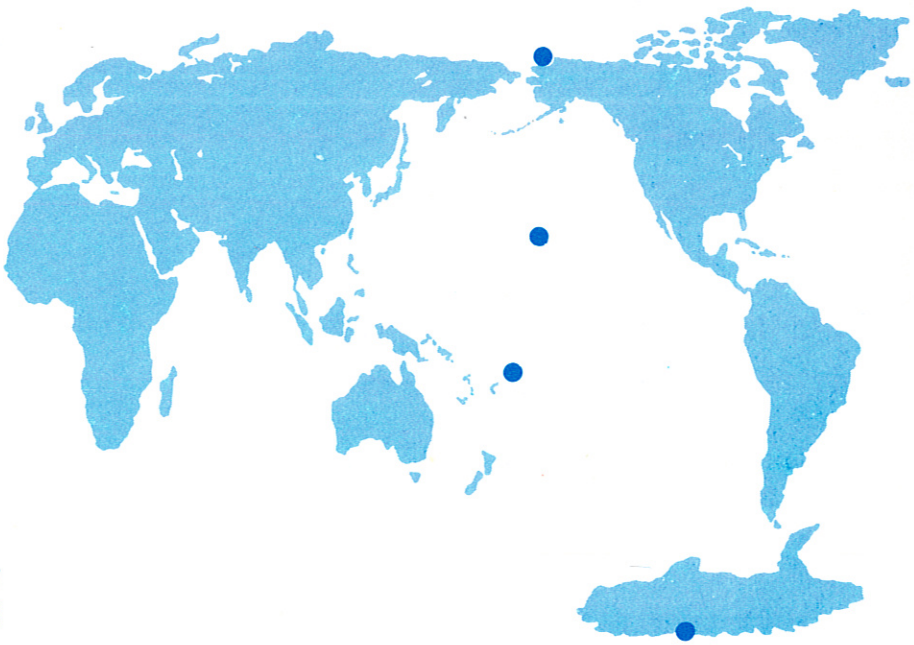
Geophysical Monitoring for Climatic Change

No. 6

Summary Report 1977



U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

ENVIRONMENTAL RESEARCH LABORATORIES

'SICAL MONITORING FOR CLIMATIC CHANGE No. 6

Geophysical Monitoring for Climatic Change No. 6

Summary Report 1977

James T. Peterson, Editor

December 1978

Boulder, Colorado

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

Environmental Research Laboratories
Wilmot Hess, Director

NOTICE

Mention of a commercial company or product does not constitute an endorsement by NOAA Environmental Research Laboratories. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

CONTENTS

FOREWORD

This report summarizes another year of measuring important atmospheric trace constituents at the four U.S. global baseline observatories and of the research associated with such measurements.

During 1977 we continued to witness an increase of both carbon dioxide and fluorocarbons in the atmosphere. In contrast, for the first time since the eruption of Mt. Agung in 1963, atmospheric transparency at Mauna Loa Observatory returned to the higher values observed during the pre-Agung years.

We are fortunate in being able to obtain information of such changes in the global atmosphere through direct observation and are pleased to share this information with associates and colleagues through this publication.

Kirby J. Hanson

Boulder, Colorado

November 16, 1978

ACRONYMS AND ABBREVIATIONS

AFGL	Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.
APCL	Atmospheric Physics and Chemistry Laboratory, Boulder, Colo. (NOAA)
ARL	Air Resources Laboratories, Washington, D.C. (NOAA)
BOSS	Basic Operating Software System
BRW	Barrow, Alaska, Observatory (GMCC)
CAF	Clean Air Facility, South Pole Observatory, Antarctica
CIRES	Cooperative Institute for Research on Environmental Science, University of Colorado, Boulder, Colo.
CIT	California Institute of Technology
DOE	U.S. Department of Energy
ECC	electrochemical concentration cell
EML	Environmental Measurements Laboratory, U.S. Dept. of Energy
EPA	U.S. Environmental Protection Agency
ERL	Environmental Research Laboratories
ETR	extraterrestrial irradiances
GATE	GARP Atlantic Tropical Experiment
GMCC	Geophysical Monitoring for Climatic Change
IC	ion chromatograph
ICDAS	Instrument Controlled Data Acquisition System
MLO	Mauna Loa Observatory (GMCC)
NBS	National Bureau of Standards
NIP	normal incidence pyrheliometer
NOAA	National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce
NWS	National Weather Service, U.S. Department of Commerce
OGC	Oregon Graduate Center, Beaverton, Ore.
PSRB	Physical Science Research Building (Boulder, Colo.)
RAPS	Regional Air Pollution Study
SIO	Scripps Institution of Oceanography
SMO	Samoa Observatory (GMCC)
SPO	South Pole Observatory (GMCC)
SRBL	Smithsonian Institution Radiation Biology Laboratory
STP	standard temperature and pressure
SUNYA	State University of New York at Albany
SUNYB	State University of New York at Buffalo
UCONN	University of Connecticut
URI	University of Rhode Island
USCGC	U.S. Coast Guard Cutter
USGS	U.S. Geological Survey
UV	ultraviolet solar radiation
WMO	World Meteorological Organization
WPL	Wave Propagation Laboratory, Boulder, Colo. (NOAA)

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE

NO. 6

SUMMARY REPORT - 1977

1. SUMMARY

1.1 Observatory Facilities

New sampling stacks were installed at all observatories to consolidate air intake systems for aerosol and gas measurements. The intake, located about 10 m above ground, was designed to provide isokinetic flow for aerosol sampling.

Modernization of the Mauna Loa Observatory was completed. The main building was insulated and weatherproofed to improve inside temperature stability. Interior walls and sleeping quarters were removed. A solar radiation tower was built, oil tanks, trailers, and a small building were removed, and a new parking lot was constructed farther from the main building. At Samoa a remote sampling tower and building were added at the upwind edge of Lauagae Ridge. Gases and aerosols are now sampled at the remote building. In January, GMCC programs at the South Pole were moved into the new Clean Air Facility, a building constructed on stilts above the snow surface that can be raised to prevent being covered by snow.

1.2 On-going Programs

Continuous analyzer CO_2 measurements continued at the four observatories; weekly flask samples continued at Niwot Ridge, Colo.; Key Biscayne, Fla.; and Cape Kumakahi, Fla. At Mauna Loa, the 1977 annual average was 1.5 ppm greater than that for 1976 and about 0.5 ppm greater than the year-to-year increases for the two previous years.

The atmospheric aerosol program was expanded to include measurements at Samoa. Four-wavelength nephelometers now are operating at all observatories except the South Pole. Pollak, Gardner, and General Electric nuclei counters are working at all four observatories.

GMCC hosted a WMO-sponsored international intercomparison of Dobson spectrophotometers. Eight nations from Europe, Asia, North America, Australia, and Africa participated. The program to modernize and calibrate foreign Dobsons continued and work was completed on 13 instruments.

The halocarbon program was expanded by including Fluorocarbon-12 and N_2O determinations in the gas chromatographic analyses of flask samples. The overall data quality was improved by using reference gases

for daily chromatograph calibrations. The GMCC reference gases were calibrated through direct intercomparison to the Oregon Graduate Center standards.

Construction of a second lidar system was completed. This system, which will be installed at Barrow after a thorough check-out, was used to obtain weekly vertical profiles of aerosol backscatter coefficient at Boulder during most of the year.

The record of atmospheric transmission of the direct solar beam begun in 1958 at MLO was continued through 1977. During late 1977, atmospheric transparency reached the high values that existed before the eruption of Mt. Agung in 1963. This was the first time since 1963 that pre-Agung transparency values had been recorded at Mauna Loa.

The precipitation chemistry program on the Island of Hawaii was expanded. Operations included bulk collectors at six sites, open-close type collectors at two sites, and a cloud water drop collector at MLO. Five cooperative programs with other institutions also were conducted at MLO.

Reduction and processing of data from routine measurements at the observatories were improved and streamlined. Support software was developed to aid project leaders in editing and certifying their measurements for archiving.

The GMCC organization was modified by forming the Aerosol and Radiation Monitoring (ARM) group to complement the Trace Gas Monitoring, Acquisition and Data Management, and Analysis and Interpretation Groups. ARM is directly responsible for the aerosol, lidar, and solar radiation measurement programs at the observatories.

1.3 Research Programs

During 1977, GMCC personnel were involved in many research projects besides the routine observatory programs. A remote sensing technique was developed to obtain vertical ozone profiles from multi-wavelength Dobson spectrophotometer measurements over a small range of solar zenith angles. The technique will be tested against real-time measurements to determine its usefulness. Analysis of historical measurements of direct solar beam intensity made by the Smithsonian Institution Astrophysical Observatory from 1923 to 1954 showed that the solar constant was constant within ±0.1%. An interagency program was begun to study the effect of urban air pollution on the receipt of incident global solar radiation. Preliminary results from urban and nearby rural measurements at St. Louis indicated that mid-city irradiances averaged only a few percent less than those outside the city.

Several GMCC scientists participated in a program to rehabilitate historical data from the United States pyranometer network. Theoretical

calculations of standard-year clear-sky solar-noon irradiance values for network sites were used to adjust network measurements for unknown instrumental, calibration, recording, and data reduction errors. Atmospheric turbidity data (aerosol optical thickness) from Raleigh, N.C., were shown to depend on air mass origin and the length of time an air parcel resided over the continental United States. Application of cloud-cover statistics to computations of a global energy budget led to studies of cloud-cover climatology, definitions, and year-to-year variations.

A good reproduction of the 1961-76 global temperature record was obtained from a simple climate model in which the main year-to-year variation was given by the MLO record of direct beam transmission. Processing and analysis of U.S. GATE surface radiation measurements continued; a report giving a complete data resume was published for use by other investigators.

GMCC sponsored a one-week workshop on monitoring the solar constant. The 40 participating scientific experts developed recommendations on what measurements are needed for climatological research and what measurements, both surface- and satellite-based, are technically feasible. A formal report is available on request.

GMCC continued to encourage investigators from other institutions to use the observatories for their research programs. Fourteen cooperating investigators contributed summaries of their projects to this report. Although all observatories were used by cooperators, most work was based at Mauna Loa.

2. OBSERVATORY FACILITIES AND PROGRAMS

2.1 Mauna Loa, Hawaii

2.1.1 Facilities

A major modernization of the Mauna Loa facilities was undertaken in 1977. The installation of the new intake system, which consolidated all gas and aerosol sampling and used one intake rather than multiple intakes, required all instrumentation to be in one building. It was decided to accomplish this consolidation and modernize the observatory, as well.

The plan developed cooperatively between the MLO and Boulder staffs required the main building to be the center of scientific measurements. The other buildings served as storage areas, workshops, or living facilities, or were removed.

To provide the best environment in the main building for the relocated instruments, the following changes were accomplished:

(1) Installation of insulation, an attic ventilator, double-pane windows, and a central air conditioner to maintain constant temperature in the building.

(2) Rewiring of the building to reduce electrical noise.

(3) Installation of the new intake system and consolidation of all measuring systems.

(4) General refurbishment of the building including removal of all interior walls, a new floor, and new paint.

The modernized interior of the new building is shown in Fig. 1.

The following improvements were made on the observatory grounds:

(1) Establishment of cooking and living facilities in another building.

(2) Removal of diesel oil tanks, two trailers, and one outbuilding.

(3) Construction of a new solar radiation tower.

(4) Installation of a ceiling in the lidar dome for better temperature control.

(5) Closing the main parking lot to the general public.

(6) Building a parking lot for public use below the observatory.

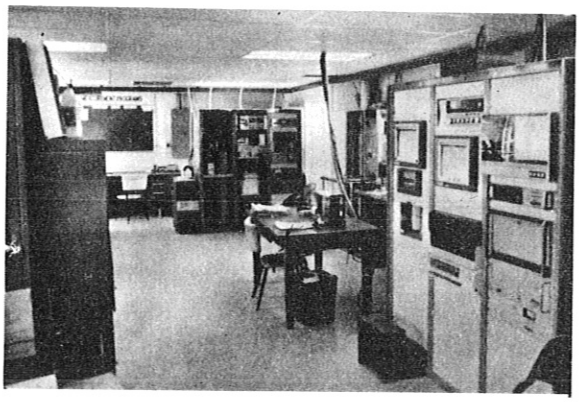


Figure 1. Interior of the modernized main observatory building at Mauna Loa.

2.1.2 Programs

The MLO programs are summarized in Table 1.

Modernization of the observatory necessitated some discontinuity in programs during and after construction. By the end of the year most programs were established in the main building and functioned properly.

The following programs were discontinued in 1977:

(1) The cooperative program with the University of Miami to measure tritium.

(2) The 13-channel radiometer.

(3) The old temperature and dew point measurement systems.

The major short-term program at the observatory was the 6-month visit by K. Coulson of the University of California at Davis. Coulson made an extensive series of measurements of the intensity and polarization of light from the sunlit sky at MLO from February to June 1977 by a high-precision polarizing radiometer. Details of the project are presented in section 6.6 of this report.

2.2 Point Barrow, Alaska

2.2.1 Facilities

During 1977, a new 1977 Chevrolet Suburban four-wheel-drive truck, purchased by GMCC, arrived at the observatory. A used 1972 International 4 x 4 crew-cab pickup, transferred to the observatory by the USGS office in Fairbanks, Alaska, also was useful and proved invaluable in October when the Suburban developed major mechanical problems that rendered it unusable for the remainder of 1977.

Table 1. Summary of Sampling Programs at Mauna Loa in 1977

Monitoring Programs	Instrument	Sampling Frequency
Gases		
Carbon dioxide	URAS-2 infrared gas analyzer	Continuous
	Evacuated glass flasks	Weekly
Surface ozone	Electrochemical concentration cell (ECC)	Continuous
	Dasibi ozone meter	Continuous
Total ozone	Dobson spectrophotometer	Discrete
Fluorocarbons	Pressurized flasks	Weekly
Aerosols		
Stratospheric aerosols	Lidar	Weekly
Condensation nuclei	Gardner counter	Discrete
	Pollak counter	Discrete
	General Electric counter	Continuous
Optical properties	Four-wavelength nephelometer	Continuous
Solar Radiation		
Global spectral irradiance	Ultraviolet radiometer	Continuous
	Five Eppley pyranometers	Continuous
Direct spectral irradiance	Eppley normal-incidence pyrheliometer	Continuous
	Filter wheel pyrheliometer	Discrete
Water vapor hygrometer	Faskett	Continuous
Meteorology		
Temperature/dewpoint	Hygrothermograph	Continuous
	Thermistor/dewpoint cell	Continuous
Pressure	Barograph	Continuous
	Pressure transducer	Continuous
Precipitation	8" raingauge	Discrete
	Tipping bucket gauge	Continuous
Wind speed/direction	Anemometer/vane	Continuous
Precipitation Chemistry		
Chemical composition of precipitation samples	pH meter, conductivity bridge, ion chromatograph	Discrete
Cooperative Programs		
Carbon dioxide - SIO	Applied Physics infrared analyzer	Continuous
	Evacuated flasks	2 mo^{-1}
Carbon monoxide - Max Planck Institut	Chemical reaction with HgO	Continuous
Total NO_2 - Aeronomy Lab/ NOAA	Spectrometer	Discrete
Surface SO_2, NO_2 - EPA	Chemical bubbler system	Every 12 days
Surface tritium - Univ. of Miami	Molecular sieve	Discrete
Total surface particulates - DOE and EPA	Hi-volume filter	Discrete/ Continuous
Atmospheric electricity - APCL/NOAA	Field mill, air conductivity device, surface antenna	Continuous
Stratospheric Aerosol - AFGL	Volz twilight photometer	Continuous
Erythema spectrum - Temple Univ.	Ultraviolet meter	Continuous
Precipitation chemistry - DOE and EPA	Precipitation collector	Discrete
Cloud water - ASRC	Cloud water collector	Discrete

The observatory's access road continued to deteriorate during the summer thaws. During this and other periods when the road was impassable to four-wheel-drive vehicles, station access was maintained by foot or use of the Bombardier, a tracked, all-terrain vehicle.

In May 1977 all GMCC aerosol and gas monitoring programs were transferred to the new sampling stack. This sampling system, designed by W. Komhyr, consolidates and standardizes the collection of gases and aerosols for the GMCC sampling programs. The sampling system was installed against the north-east wall of the "clean air" room and extends through the observatory's roof to approximately 10 m above the surrounding tundra. At present, gases for the CO_2 continuous analyzer, GMCC CO_2 flask samples, surface ozone analyzers, fluorocarbon flask samples, condensation nuclei for the Pollak, Gardner, and G.E. counters, and aerosols for the four-wavelength nephelometer are collected through the sampling system.

2.2.2 Programs

A hand-operated, normal incidence pyrheliometer (NIP) with a filter wheel was added to the observatory's equipment in April (Table 2). In May this NIP and the station quartz-dome pyranometer were compared with GMCC standards by B. Mendonca during a visit to the observatory.

In November, McMillan ozone generator #313 was put into operation for weekly calibrations of the DASIBI and ECC meters. The McMillan generator replaced Reginer generator #29. During August 1977 use of the new gas sampling system started for the collection of fluorocarbon samples. A stainless-steel bellows pump flushes and pressurizes two flasks simultaneously. The old hand-held evacuated flask sampling system was continued through November to check the performance of the new sampling system.

Another attempt at collecting uncontaminated precipitation samples for the GMCC precipitation chemistry program was made at the Barrow Observatory by J. Miller of GMCC in September. The samples are sent to MLO for analysis. The small amounts of precipitation and the common high winds of the Barrow area make precipitation collection difficult. The instrumentation control and data acquisition system (ICDAS) was upgraded in December when BOSS 76186 was replaced by BOSS 77280. In February, W. Henderson, Aeronomy Lab, NOAA, upgraded his nitrogen oxide program by installing a computer-controlled spectrometer system that is completely automatic with scanning control and data logging by a NOVA-3 minicomputer.

Table 2. Summary of Sampling Programs in Barrow in 1977

Monitoring Programs	Instrument	Sampling Frequency	Data Record
Gases			
Carbon dioxide	UNOR infrared analyzer	Continuous	Mar 73-present
	Evacuated glasss flask	1 wk^{-1}	Apr 71-June 75
	Pressurized flask pairs	1 wk^{-1}	Jun 75-present
Surface ozone	Electrochemical concentration cell (ECC)	Continuous	Mar 73-present
	Dasibi ozone meter	Continuous	Jul 75-present
Fluorocarbons	Evacuated flask	1 wk^{-1}	Sep 73-Dec 77
	Pressurized simultaneous flask sample	1 wk^{-1}	Aug 77-present
Total ozone	Dobson spectrophotometer	Discrete	Aug 73-present
Aerosols			
Condensation nuclei	Gardner counter	Discrete	Sep 76-present
	Pollak counter	Discrete	Jul 73-present
	G.E. condensation nucleus counter	Continuous	May 73-Nov 74 Apr 76-present
Optical properties	4-wavelength nephelometer	Continuous	Apr 76-present
Solar Radiation			
Global spectral irradiance	Four Eppley pyranometers	Continuous	Jun 74-present
	Ultraviolet radiometer	Continuous	Jun 74-present
Direct spectral irradiance	Eppley normal incidence Filter wheel pyrheliometer	Discrete	Apr 77-present
Meteorology			
Temperature	Hygrothermograph	Continuous	Feb 73-present
	Thermistor	Continuous	Nov 75-present
Air pressure	Microbarograph	Continuous	Feb 73-present
	Mercurial barometer	Discrete	May 74-present
	Transducer	Continuous	Nov 75-present
Precipitation chemistry GMCC	Wide-mouth polyethylene collector (sample anlayzed at MLO)	Discrete	Sep 77-present (present method)
Winds speed/direction	Bendix aerovane		
	Strip chart	Continuous	Feb 73-present
	Mag tape record	Continuous	Apr 75-present
Ground temperature	Thermistor	Continuous	Nov 75-present
Cooperative Programs			
Total surface particulates - DOE	Hi-volume sampler	Discrete	Aug 75-present
Arctic haze particulates - URI	Hi-volume sampler (celluloid filter)	Continuous	Sep 76-present
	Low-volume sampler (glass-fiber filter)	Continuous	Sep 76-present
Global radiation - SRBL	Eppley pyranometers	Continuous	Apr 73-present
	Scanning UV radiometer	Continuous	May 75-present
Total NO_2 Aeronomy Lab/NOAA	NO_2 spectrometer	Discrete	Aug 75-Feb 77
		Continuous	Feb 77-present
CO_2 sampling - SIO	Evacuated flask	2 sets mo^{-1}	Jan 74-present

2.3 Samoa

2.3.1 Facilities

Important additions to the Samoa GMCC facilities during 1977 were a remote sampling building and a remote sampling tower. These structures were sited at the upwind end of Lauagae Ridge, approximately 400 feet (120 m) northeast of the main observatory building. All gaseous and aerosol sampling now is conducted from the remote sampling site. The remote sampling tower is 42 feet tall, and the gas/aerosol sampling stack designed by W. Komhyr is attached to the tower. The base of the gas sampling stack is located in the remote sampling building adjacent to the base of the tower. Approximate height of the gas/aerosol intake is 50 feet above the ridge.

The remote sampling building is a prefabricated 8 x 8 x 16 ft structure supplied by ELDER International of Houston, Texas. All signal/electrical wiring between the main building and remote building is housed in underground conduits along with air lines for the analyzers in the main building. (At this time, the URAS CO_2 instrument is the only analyzer in the main building.)

2.3.2 Programs

The major addition to GMCC Samoa programs (Table 3) during 1977 was the installation of aerosol monitoring equipment consisting of a Pollak condensation nucleus counter, a General Electric continuous condensation nucleus counter, and a four-wavelength nephelometer. B. Bodhaine visited the observatory in July to oversee equipment installation.

During July the halocarbon sampling program was modified by installing a stainless steel bellows pump to draw air from one of the outlets of the gas sampling stack in the remote sampling building. In January, a spectrometer for total NO_2 measurements (cooperative program led by W. Henderson, NOAA) was installed in the main observatory building. Data acquisition and control units for the system were placed in the GMCC data room. The spectrometer was attached to one of the instrument platforms on the observatory roof.

Additions to the solar radiation program in 1977 included two NIP units. In January, a NIP with four-position filter wheel (clear, OG1, RG2, and RG8 filters) was installed. In November, a second NIP unit, attached to an Eppley equatorial mount solar tracking system, was installed. Two new Eppley horizontal incidence pyranometers with OG1 and RG8 filter domes were received in May as replacements for the two original sensors. The domes of the original pyranometers had deteriorated significantly after only approximately one year of operation and exposure in the Samoan tropical, maritime environment.

Table 3. Summary of Sampling Programs at Samoa in 1977

Monitoring Programs	Instrument	Sampling Frequency
Gases		
Carbon dioxide	URAS 2T infrared gas analyzer	Continuous
	Glass flasks	Discrete(1 wk^{-1})
Surface ozone	Electrochemical concentration cell	Continuous
	Dasibi ozone meter	Continuous
Total ozone	Dobson spectrophotometer	Discrete
Fluorocarbons	Flask sampling	Discrete (1 wk^{-1})
Aerosols		
Condensation nuclei	Gardner counter (LED long tube)	Discrete
	General Electric CNC	Continuous
	Pollak counter	Discrete
Optical properties	Four-wavelength nephelometer	Continuous
Solar Radiation		
Global spectral irradiance	Four Eppley pyranometers with quartz, GG22, OG1, RG8 filters	Continuous
Direct spectral irradiance	Eppley normal incidence pyrheliometer with filter wheel	Discrete
	Normal incidence pyrheliometer on equatorial mount	Continuous
Meteorology		
Temperature (air)	Thermistor	Continuous
	Hygrothermograph	Continuous
	Max/min thermometers	Discrete
Temperature (soil)	Psychrometer	Discrete
	Thermistor	Continuous
Relative humidity	Hygrothermograph	Continuous
	Psychrometer	Discrete
Wind speed/direction	Bendix aerovane	Continuous
Pressure	Transducer (capacitance type)	Continuous
	Microbarograph	Continuous
	Mercurial barometer	Discrete
Precipitation Chemistry		
pH	Samples analyzed at MLO by ion chromatograph	Discrete
Conductivity		Discrete
Cooperative Programs		
Total particulate loading of surface air - DOE/EML	Hi-volume sampler	Continuous
Turbidity - EPA/NOAA	Volz sunphotometer	Discrete
Stratospheric aerosol-AFGL	Volz twilight photometer w/filters	Discrete
Rain collection - DOE/EML	Wet/dry collectors (HASL)	Continuous
Rain collection - EPA	Misco collector	Continuous

2.3.3 Special Programs

In May of 1977 C. Patterson (Cal Tech) returned to Samoa GMCC to collect aerosol samples for lead analysis. This was the third trip of a series begun in 1976 to collect aerosol samples from dry deposition, precipitation washout, and volumetric air sampling through filters.

W. Fitzgerald and an assistant used the Samoa GMCC facilities for about one week in October to collect air samples for analysis of mercury.

2.3.4 Expected 1978 Additions to SMO Programs

A continuous halocarbon sampling program funded by the Manufacturing Chemists Association (principal investigator R. Rasmussen of the Oregon Graduate Center) is scheduled for installation during May/June 1978. An additional prefab structure will be erected adjacent to the remote sampling tower and a Hewlett Packard gas chromatograph will be installed, together with necessary carrier and calibration gas tanks. The program is expected to continue for 3 to 5 years.

2.4 South Pole

2.4.1 Facilities

The GMCC South Pole monitoring programs were carried out in the old sub-surface Clean Air Facility (CAF) during November and December 1976. In January 1977, the programs were moved to a new building constructed above the snow surface (Fig. 2). The location of the new CAF in relation to the main station and the old CAF can be seen in Fig. 2. GMCC projects operated during the first year of the new CAF, as well as projects operated cooperatively for other investigators, are listed in Table 4. Figures 3, 4, and 5 show the locations of sensors in and around the new CAF.

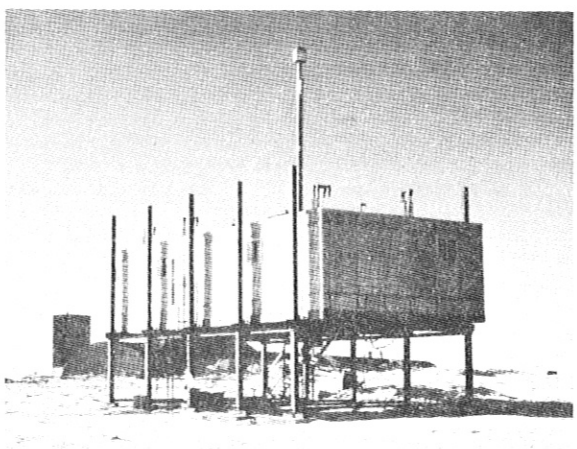


Figure 2. New Clean Air Facility constructed during the 1976-1977 summer. The main station is in the background.

Table 4. Summary of Sampling Programs in South Pole in 1977

Monitoring Programs	Instrument	Sampling Frequency	Data Record
Gases			
Carbon dioxide	URAS infrared gas analyzer	Continuous	Jan 75-present
	Evaculated glass flask	2 mo^{-1}	Jan 75-present
Surface ozone	Electrochemical concentration cell (ECC)	Continuous	Dec 71-present
	Dasibi ozone meter	Continuous	Jan 76-present
Total ozone	Dobson spectrophotometer	Discrete	Dec 63-present
Fluorocarbons	Stainless steel sampling cylinders	1 mo^{-1} except 2 mo^{-1} during summer	Jan 77-present
Aerosols			
Condensation nuclei	General Electric counter	Continuous	Jan 74-present
	Pollak counter	Discrete	Jan 74-present
Solar Radiation			
Global spectral irradiance	Four Eppley pyranometers with quartz, GG22, OG1, and RG8 filters	Continuous during daylight period	Feb 74-present
	Ultraviolet radiometer	Continuous during daylight period	Feb 74-present
	Normal incidence pyrheliometer	Continuous during daylight period	Oct 75-present
	Filter wheel normal incidence pyrheliometer with quartz, OG1, RG2, and RG8 filters	Discrete during daylight period	Jan 77-present
Meteorology			
Air temperature	Thermistor	Summer only	Dec 75-Jan 78
Snow temperature	Thermistor	Summer only	Dec 75-Jan 78
Air temperature	Thermistor	Continuous	Mar 77-present
Snow temperature	Thermistor	Continuous	Jul 77-present
Pressure	Transducer	Continuous	Dec 75-present
Wind speed/direction	Bendix aerovane	Continuous	Dec 75-present
Moisture	Dupont moisture monitor	Continuous	Mar 77-present
Cooperative Programs			
CO_2 sampling - SIO	Evacuated glass flask	2 mo^{-1}	1955-present
Total surface particulates - DOE	Hi-volume filter	Intermittent	May 70-present
Turbidity - NOAA/ARL	Dual wavelength sunphotometer	Discrete	Jan 74-present
C-14 sampling - NOAA/ARL	Pressurized steel flask	1 wk^{-1}	Jan 74-present
Atmospheric electricity - NOAA/APCL	Atmospheric conductivity meter Electric field mill Air-earth current apparatus	Continuous	
Thermal radiation budget - NOAA/APCL	Net infrared radiometer	Continuous	
Acoustic echo sounder studies - NOAA/WPL	Acoustic sounder system Four microbarographs $(C_T)^2$ sensor	Continuous	
Ionospheric absorption - Univ. of Calif., San Diego	30 and 50 MHz riometers	Continuous	

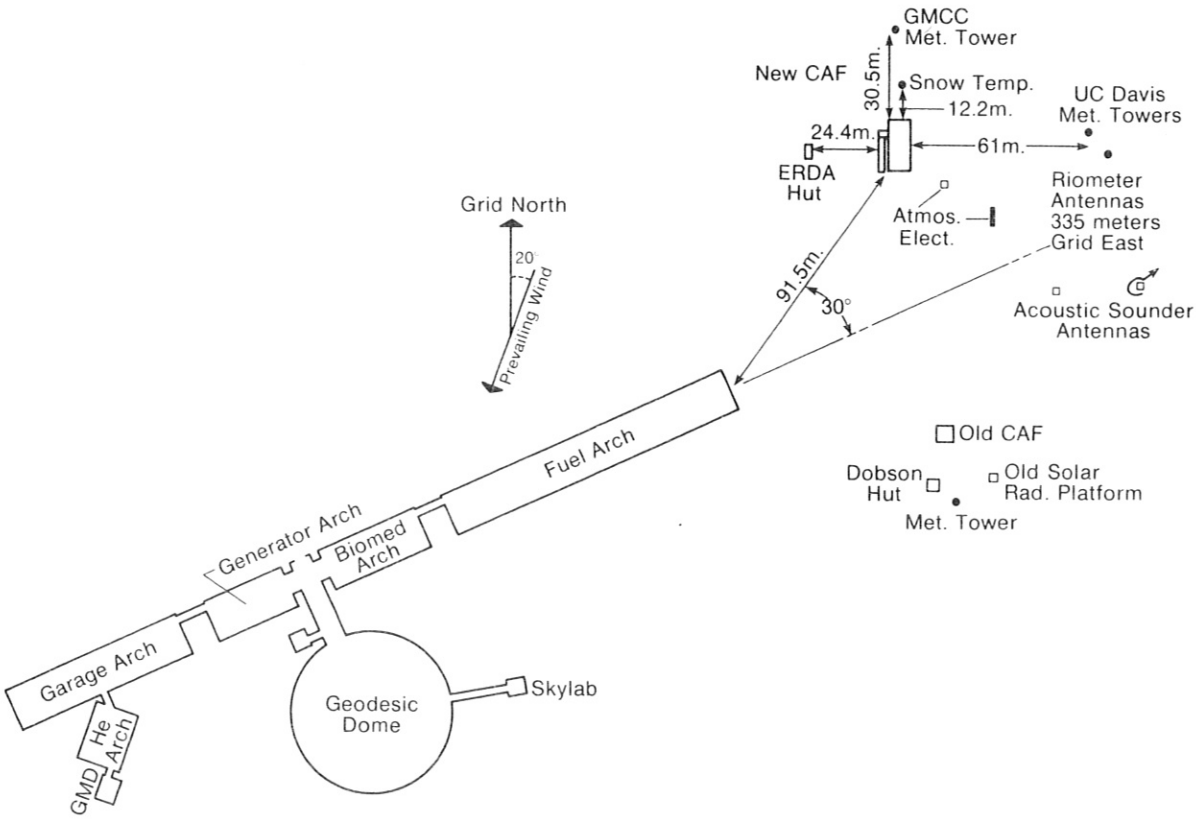


Figure 3. Amundsen-Scott Station, South Pole, Antarctica, 1977.

The wooden building is set on steel cross beams supported approximately 5 m above the snow surface by ten vertical steel beams. It can be raised on the supporting beams as snow drifts higher around the building. The beams are set on large wooden bases that rest on the snow surface.

Separate aerosol and gas sampling stacks extending approximately 6 m above the CAF roof and 13.5 m above snow surface were installed near the grid northeast corner of the building. Outside air is drawn through the sampling stacks by blowers inside the monitoring room.

The Dobson and solar radiation rooms were provided with windows that open so that observations could be made from inside the building. A roof hatch over the Dobson room makes zenith observations possible. Curtains for thermal isolation of the Dobson and solar radiation rooms during observations did not arrive until almost the time for winter station closing. Since routine observations had been made without them with no problems, they were not installed.

Electric heaters in the building were more than adequate to keep room temperature at about 17°C, even when outside temperature was about

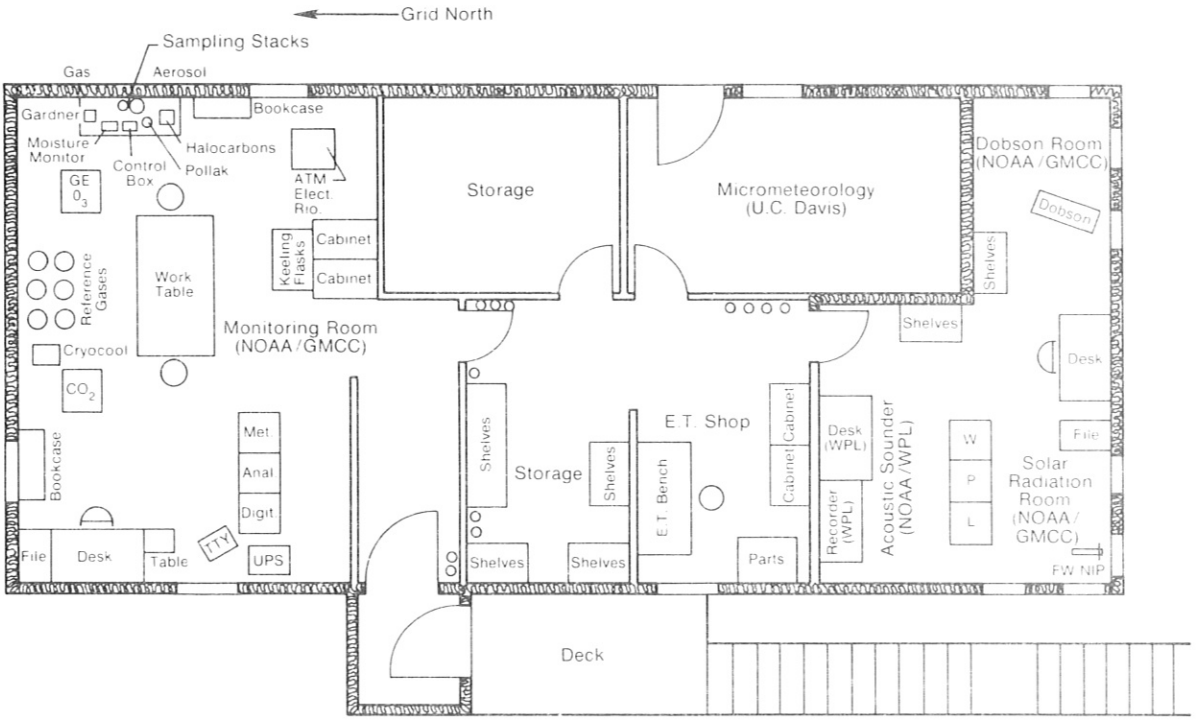


Figure 4. Interior plan of new Clean Air Facility, South Pole, Antarctica, 1977.

-70°C. Temperature inside the building was fairly sensitive to outside wind strength, however, and increasing winds sometimes caused room temperature to drop 5°C.

During the year, very little drifting snow accumulated directly beneath the building. Drifts of 2 to 5 ft accumulated around the periphery of the building, especially near the downwind grid southwest corner. The building appeared to be settling on its base supports; by the end of the winter gaps of ¼ in or so had appeared between ceiling and walls and between walls and floor.

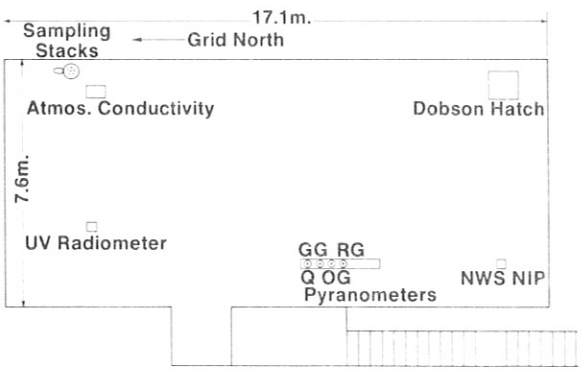


Figure 5. Roof plan of new Clean Air Facility, South Pole, Antarctica, 1977.

2.4.2 Programs

Carbon Dioxide

The CO_2 sampling system was operated using the working reference gases once an hour. The weekly calibration was converted to control of reference gases by ICDAS relay register when BOSS 76186 was started.

Throughout the year, the URAS-2T analyzer exhibited a continuous upscale drift which necessitated adjustment of the instrument zero every two weeks or so. Short-period upscale and downscale zero drift occurred in November 1976 and in April and October 1977, in connection with erratic operation of the heater fan motor caused by bad bearings.

A pair of flask samples was obtained twice monthly throughout the year. The 0.5 ℓ evacuated flasks were filled from the analyzer air sample line by diverting the air flow from the analyzer during the 10 minutes of the hour when the working reference gases were flowing through the analyzer sample chamber.

Surface Ozone

With BOSS 76186, calibration of the ECC and Dasibi became semi-automatic. Calibration data were transferred automatically by ICDAS to the appropriate locations in the D array. An ozone partial pressure of 50 nanobars for high calibration was supplied by the McMillan MEC 1000 ozone generator, which was calibrated against a traveling standard ECC meter in January.

The Dasibi had relatively few problems during the year, although the ozone partial pressures it gave during high calibration were consistently 20% low compared with the MEC 1000 value. The output from the ECC meter was often noisy or erratic. Replacing leaky air pumps in March and April helped temporarily. In July, sensor ECC 005-2 #2 was replaced by sensor ECC 005-4 #1 to correct a negative meter output. Solution pumps were replaced in March and May when the rubber tubing developed leaks.

Total Ozone

The Dobson spectrophotometer was moved from the Dobson hut to the Dobson room of new CAF during the second week of January. Sun or zenith observations were made in mid-morning, at noon, and in mid-afternoon local time. During the dark period, moon observations were taken less frequently when enough instrument sensitivity could be obtained. Quasi-simultaneous observations were made during the austral summer to compare zenith and sun observations, and observations at different wavelengths. Mercury lamp, standard lamp, and sensitivity tests were performed at the end of each month. In February, the Table of Settings of Q dated January 1973 was amended according to the following:

Wavelength	Setting Change
A	add 0.25
C	add 0.40
D	add 0.40

The spectrophotometer operated with no problems during the year, and needed no repairs.

Halocarbons

A revised method of obtaining ambient air samples for halocarbon analysis was begun in the new CAF. The sampling system consisted of a stainless steel bellows pump attached to one port of the gas sampling stack by a precleaned stainless steel tube. Two 300-ml, double-ended stainless steel flasks were attached in parallel to the front of the pump for purging and pressurizing with outside air. Four pairs of cylinders were pressurized with sample air in late January and early February and returned to Boulder. For the rest of the year, one pair of samples was taken monthly, stored in the new CAF, and shipped to Boulder for analysis the next November.

Aerosols

Surface aerosols at South Pole were monitored periodically with Pollak and long-tube Gardner condensation nucleus counters. The modified General Electric condensation nucleus counter provided a continuous record. Sample air for each instrument was obtained isokinetically from the aerosol sampling stack.

Twice daily observations were made with the Pollak counter, one at the time of the morning radiosonde and the other in the evening. The instrument operated without problems throughout most of the year. Consistent readings of 15 to 25 n cm^{-3} were obtained during the austral winter, and on a few occasions during summer (not caused by local contamination), condensation nucleus counts were more than 1000 n cm^{-3} for almost a day.

The Pollak counter was used as the standard by which to set the G.E. counter. Within a narrow range of nucleus concentrations, G.E. values stayed fairly close to Pollak values. However, a substantial change in nucleus concentration required the G.E. counter to be reset to track the Pollak. In February, the G.E, vacuum chamber and photomultiplier tube light path were cleaned, and the instrument was aligned to get the proper waveform. A bad FET switch in the dynamic background-suppress-circuitry caused some down time in March. Both photosense assemblies were replaced at this time. The right-angle housing was replaced in August because a broken brass sleeve was allowing excessive play in the shaft.

The long-tube Gardner counter was not used regularly during the winter because of very low nucleus concentrations. Fogging of the lower lens after one or two successive samples seemed to affect the readings at low nucleus concentrations.

Solar Radiation

Solar radiation data collection continued at the old CAF during November and December 1976. The NWS NIP tracking the sun on an equatorial mount, the UV radiometer, and four horizontal incidence pyranometers were operated on the old solar radiation platform. Signals from the instruments were amplified for ICDAS by rather unstable Newport amplifiers. From November until early February, a traveling standard quartz pyranometer was connected to ICDAS for comparison with the station quartz pyranometer.

In January 1977, the solar radiation sensors were moved to the roof of the new CAF. The four station pyranometers and the quartz standard were placed on a stand approximately 1.7 m above the roof. The NWS NIP and UV radiometer were placed on separate stands, as they were at the old location. The new solar radiation amplifiers installed at the end of December were much more stable than the old Newports. Once the calibrations of these amplifiers were set, they rarely required recalibration.

Filter wheel NIP observations were begun in the new CAF in January. The instrument was mounted on a tripod inside the solar radiation area and was aimed manually at the sun through an open grid south-facing window. Output voltages were read three times daily, sky conditions permitting, from a DVM connected to the instrument.

A new pyranometer de-icer system was tested during the remainder of the sunup period after the move to the new CAF. The system pumped air, unheated except for heat added by the two air pumps, through tubing to metal collars fitted around the chassis of each pyranometer. Two small holes in the collar allowed air to flow over the dome. This arrangement failed to keep ice off the quartz and GG22 domes, perhaps because ice buildup inside the air lines and at the collar blocked air flow. Heat taping and insulating the air lines did not help.

A modified pyranometer de-icer system was put into operation in October after sunup. A small electric heater was placed inside the pump box to keep the temperature in the 20°C to 30°C range, and the air lines were heat taped and insulated. The OG1 and RG8 domes, which usually stayed clear of ice without a de-icer system, were excluded from this arrangement. The modified deicer system kept the quartz and GG22 domes free of ice, but the warmer air in contact with the instrument chassis may have produced a temperature gradient across the cold junction.

Meteorology

The Bendix Aerovane was moved to the top of a new 10-m tower, 30-m grid north of the new building. The air temperature sensor was placed on the new tower approximately 3 m above the snow surface, and the snow temperature sensor was buried 1 m beneath the snow surface about 12-m grid north of the new CAF. The pressure transducer was brought from approximately 7 m below snow surface inside the old CAF to about 5.5 m above snow surface in the new CAF monitoring room.

New Sensor Electronics temperature sensors were installed at the new CAF. The new sensors have a linear range between -50°C and -80°C. Both snow and air sensors were calibrated against a -100°C to +50°C alcohol-in-glass thermometer in an isopropyl alcohol bath. After recalibration of the snow temperature card, both sensors were within 0.5°C of the alcohol thermometer over the range of temperatures at South Pole. The new air temperature sensor was put on line in early March, and the new snow sensor went into operation in July. The unaspirated air sensor was mounted on the meteorological tower about 2 m above the snow surface; the snow sensor was placed next to the old snow sensor.

The difficulty of recording wind directions on ICDAS near 360° continued sporadically. The wind speed card also gave problems in early February. The reference voltage intermittently became unstable, and wind speeds of nearly 60 mi h^{-1} were recorded. In August, the wind speed transmitter began stalling at about 5 mi h^{-1} because of bad bearings. A replacement transmitter stalled at about 2 mi h^{-1} throughout September and October. At the end of October, lubricating the bearings eliminated the stalling, but dismantling the transmitter to reach the bearings changed the calibration. Instead of being close to speeds indicated by the New Zealand Meteorological Service Aerovane as before, indicated speeds were about 30% lower.

A Dupont 303 moisture Monitor was connected to ICDAS in March. The instrument, which began operating shortly after the move to the new CAF, was used to obtain moisture readings in conjunction with the twice daily Pollak observations. Outside air for the monitor was drawn from a port on the gas sampling stack by a Dynapump. ICDAS recorded voltages from the instrument but did not convert them to moisture values. The instrument operated without problems during the year although bad bearings and worn diaphragms in the Dynapump caused some down time.

ICDAS

ICDAS went back into operation on November 21, 1976, after being inoperative since September because of a bad IC in the NOVA CPU. ICDAS was operated with BOSS 75330 until December 26 when BOSS 76186 replaced it. The Deltech uninterruptible power supply (UPS) was connected to ICDAS in early February 1977, after the move to the new CAF. Except for two weeks in March, the UPS worked well during the year, eliminating the

need to restart BOSS and reposition the data tape after station power failures. ICDAS operated throughout the year with no extended periods of down time. The NOVA malfunctioned three times during the year.

2.5 Boulder, Colorado

2.5.1 Facilities

Three facilities in Boulder and vicinity are available to the GMCC program. One consists of seventh (top) floor laboratory space and platform space on the roof of the University of Colorado Physical Science Research Building (PSRB) No. 3, headquarters of the GMCC program. The roof space is well suited for solar radiation measuring and contains astronomical observation domes for the solar radiation and total ozone programs. The second facility is located at NOAA's Fritz Peak Observatory, operated by the NOAA Aeronomy Laboratory. This observatory is about 40 km west of Boulder at an elevation of 2.4 km above mean sea level. The site is especially suited for testing and operating clean air gas analysis instrumentation. Prevailing winds at the observatory are from the west, the direction of the Rocky Mountain Continental Divide.

The third facility is at Niwot Ridge, at 3.6-km elevation near the Continental Divide. Air samples for CO_2 and Freon-11 analyses are collected there once a week under contract with the University of Colorado Institute of Arctic and Alpine Research (INSTAAR). This high-altitude location is regarded as a midcontinent clean air site. Data from here are often comparable in quality with data obtained at the GMCC baseline stations.

2.5.2 Programs

Total Ozone

This continuing program started in Boulder in 1966. Measurements are made on the roof of PSRB-3 with Dobson ozone spectrophotometer No. 82. Observational data are processed routinely, and results are sent to the Atmospheric Environment Service, Department of the Environment, Toronto, Ontario, Canada, for publication in Ozone Data for the World.

Solar Radiation

Solar radiation is measured intermittently to calibrate pyranometers and pyrheliometers for use at the GMCC baseline stations. Pyranometers and pyrheliometer intercomparisons are conducted with standards maintained by the NOAA/ARL Solar Radiation Facility.

The NOAA Solar Radiation Facility, located with GMCC in PSRB-3, is

responsible primarily for maintaining calibration standards and calibrating pyranometers and pyrheliometers used in the United States network. The Solar Radiation Facility routinely monitors total global radiation, global radiation in broad wavelength bands (longer than 295, 395, 530 and 695 nm), and diffuse and direct radiation.

Atmospheric Turbidity

Measurements of atmospheric turbidity were made throughout 1977 from PSRB-3 in Boulder. A dual wavelength (380 and 500 nm) sunphotometer was employed for the measurements.

Ultraviolet Radiation

Testing and development began on an instrument to measure spectral ultraviolet radiation on the PSRB-3 roof. A double monochrometer has been modified to measure diffuse and direct components of downward-directed irradiance. Instrument performance is being evaluated for investigation of the variability of UV radiation in the spectral region that affects tanning of the skin. Measurements are made intermittently.

Lidar

In September 1977 a new lidar system began operation from the seventh floor laboratory of PSRB-3. Vertical profiles of aerosol backscatter coefficient are made about once a week. These weekly observations are part of a program to test this new lidar system. After completion of these tests (probably during 1979), the system will be shipped to the Barrow Observatory for routine use.

Surface Ozone

The program to measure ozone at Fritz Peak Observatory in the mountains west of Boulder was continued in 1977. Observations with an ECC meter were terminated about mid-year, but measurements continued with a Dasibi meter. Study of the data indicates that summer and fall observations often are contaminated by air from the Denver area.

Ozone measurements with an ECC meter were continued in Boulder. In addition, new ozone measurements were begun in 1977 in cooperation with the Boulder County Health Department. A McMillan chemiluminescent ozone analyzer is used for the measurements. Data recorded are used for issuing daily air quality reports for the Boulder Valley.

Carbon Dioxide

A flask CO_2 sampling program was continued near Boulder at Niwot Ridge, under contractual arrangements with INSTAAR. This cooperative monitoring effort began in June 1969 but was interrupted from May 1973 to December 1975. Pairs of flask air samples are collected on a weekly

basis at Niwot Ridge and delivered to the GMCC Laboratory for CO_2 analysis by infrared analyzers.

Halocarbons

Under contractual arrangements with INSTAAR, a program to monitor Freon-11 (CCl_3F) at Niwot Ridge, Colo., begun in January 1976, was continued through 1977. Pairs of samples are collected in stainless steel cylinders at weekly intervals and delivered to Boulder for CCl_3F analysis by chromatographic means.

3. CONTINUING GMCC PROGRAMS

3.1 Carbon Dioxide

3.1.1 Continuous Analyzer Measurements

During 1977, atmospheric CO_2 concentrations were monitored continuously by non-dispersive infrared gas analyzers at the four GMCC observatories. In most instances these measurements were digitally recorded on-site by ICDAS, and an analog record was obtained simultaneously with a strip chart recorder.

Computer programs have been written to process the continuous analyzer data; these replace the preliminary programs described in the GMCC Summary Report 1974 (p. 15-16). The new programs use reference gas concentrations and mean analyzer output voltages in computing mean hourly atmospheric CO_2 values. The mean atmospheric CO_2 values from ICDAS are compared hour-by-hour with the strip chart record. The data are then edited to delete from the record erroneous values, resulting from instrument or recorder malfunctions, etc. Hours when strip charts showed a variable CO_2 trace were coded but retained in the records. The strip charts were also used to recover continuous analyzer data when there were no ICDAS records.

The provisional monthly mean CO_2 values in this report were calculated from all hourly values retained in the record, including the variable values. All data are expressed in the Scripps 1959 Adjusted Index Scale (Keeling et al., 1976). The small differences between monthly means reported here and in other publications (e.g., Peterson et al., 1977; previous Summary Reports) result from the improved data editing process.

Table 5 lists the provisional monthly mean data for the GMCC observatories, the number of hours of record, and the fraction of the month

Table 5. 1977 Provisional CO_2 Continuous Analyzer Monthly Mean Concentrations*

	Barrow, Alaska			MLO, Hawaii			Samoa			South Pole		
	h of Data	% of Month	Mean Conc. (ppm)	h of Data	% of Month	Mean Conc. (ppm)	h of Data	% of Month	Mean Conc. (ppm)	h of Data	% of Month	Mean Conc. (ppm)
Jan	722	97.0	338.64	606	81.5	328.74	665	89.4	327.17	625	84.0	325.21
Feb	632	94.0	338.84	500	73.7	329.18	628	93.5	326.73	604	89.9	326.01
Mar	714	96.0	340.05	715	96.1	330.64	627	84.3	327.50	713	95.8	325.88
Apr	688	95.6	340.89	695	96.5	331.74	591	82.1	327.42	688	95.6	325.93
May	665	89.4	341.06	699	94.0	332.37	527	70.8	327.75	711	95.6	326.05
Jun	694	96.4	339.66	575	79.9	331.97	603	83.8	328.74	652	90.6	326.18
Jul	700	94.1	332.48	629	84.5	330.41	538	72.3	328.35	707	95.0	326.43
Aug	699	94.0	329.30	706	94.9	328.44	660	88.7	328.20	715	96.1	326.77
Sep	696	96.7	330.50	680	94.4	327.22	241	33.5	327.96	689	95.7	327.11
Oct	717	96.4	334.40	714	96.0	327.36	515	69.2	329.11	705	94.8	327.42
Nov	689	95.7	336.98	692	96.1	328.56	458	63.6	329.29	648	90.0	327.41
Dec	704	94.6	340.61	724	97.3	330.11	615	82.7	330.53	700	94.1	327.12

*Data are expressed on the Scripps 1959 Adjusted Index Scale.

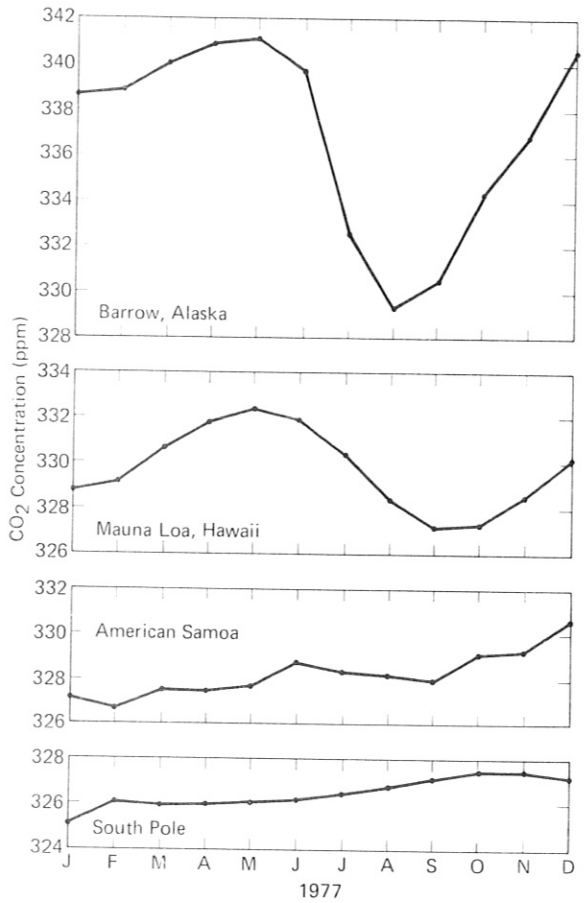


Figure 6. 1977 provisonal CO_2 continuous analyzer monthly mean concentrations for Barrow, Alaska, Mauna Loa, Hawaii, Samoa, and the South Pole. Data are expressed on the Scripps 1959 Adjusted Index Scale.

represented by these data. The only planned interruption in the continuous record is the weekly instrument calibration check which requires 5 to 6 h. Thus, valid data can be obtained 96% to 97% of the time. In 1977, 18 of the 48 station-months had more than 95% representation and in 30 station-months, data were obtained for at least 90% of the time. The smallest percentage (33.5%), resulting from analyzer failure, occurred in September at Samoa.

The CO_2 concentration data of Table 5 are plotted in Fig. 6. The characteristics of the annual variations in the data from Barrow, Mauna Loa, and the South Pole are consistent with the results obtained from other continuous analyzer monitoring programs (Bolin and Keeling, 1963; Pales and Keeling, 1965; Keeling et al., 1976; Kelley, 1969). The month with minimum concentration varies as a function of latitude, and is most evident in the Barrow and Mauna Loa data; the decrease of the annual oscillation from north to south is evident in all four curves.

There is a reasonable correspondence between the GMCC Samoa and the Bolin and Kelling 12.5°S data for the first 9 mo. Thereafter, they

Table 6. Provisional Monthly Average Atmospheric CO_2 Concentrations (PPM), at MLO, Hawaii, and Year-to-Year Increase of Monthly Average (ΔCO_2)*

Month	1975	ΔCO_2 1975-76	1976	ΔCO_2 1976-77	1977
Jan	327.03	0.74	327.77	0.97	328.74
Feb	327.81	0.89	328.70	0.48	329.18
Mar	328.25	1.16	329.41	1.23	330.64
Apr	329.30	1.24	330.54	1.20	331.74
May	329.89	0.84	330.73	1.64	332.37
Jun	329.36	0.90	330.26	1.71	331.97
Jul	327.66	1.22	328.88	1.53	330.41
Aug	325.88	0.94	326.82	1.62	328.44
Sep	324.61	0.77	325.38	1.84	327.22
Oct	324.85	0.34	325.19	2.17	327.36
Nov	325.69	0.77	326.46	2.10	328.56
Dec	(326.28)	----	328.12	1.99	330.11
Annual Average		0.89		1.54	

*Data are expressed in the Scripps 1959 Adjusted Index Scale.

diverge; the former climbs steadily whereas the latter, consistent with the latitude shift, decreases to a minimum in November. The apparent CO_2 increase at Samoa from October through December may be an instrumental artifact resulting from moisture condensed from sampled air in the plastic sampling lines. Such condensation was eliminated in February 1978. These data will be studied further during analysis of the 1978 continuous record.

The low monthly average for January at the South Pole is probably an instrumental artifact caused by changing infrared sources in the analyzer. The January mean CO_2 concentration may be about 1 ppm low when referenced to the baseline for the year's data. This conclusion is corroborated by flask sample data.

Data for 1975 and 1976 from Mauna Loa Observatory have also been collected and edited by new procedures. Monthly mean CO_2 values are listed in Table 6 (an updated version of Table 1 in Peterson et al., 1977). The average annual increases are calculated from the monthly increases. Values for December 1975 are not included because only 29 h of data were recorded. The 1975 through 1977 monthly averages at MLO are plotted in Fig. 7. The annual cycle of about 6-ppm amplitude and the long-term secular increase are clearly evident.

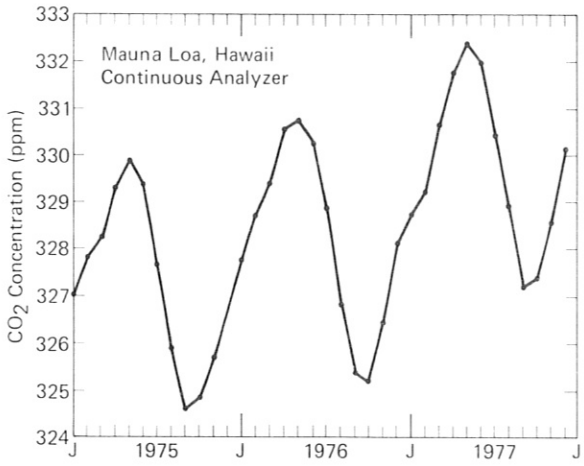


Figure 7. Provisional CO_2 continuous analyzer monthly mean concentrations for Mauna Loa, Hawaii, for 1975 through 1977. Data are expressed on the Scripps 1959 Adjusted Index Scale.

3.1.2 Flask Sample Measurements

At each station during 1977, 500-cm^3 glass flasks were filled with air from the CO_2 analyzer air intake system. The samples were collected in pairs simultaneously. One pair of samples was collected each week at Barrow, Mauna Loa, and Samoa; pairs were collected twice per month at the South Pole. Flasks were returned to Boulder from Barrow, Mauna Loa, and Samoa as soon as possible after they were collected. They were analyzed in batches at intervals of several weeks. January and February samples from the South Pole were returned before the February station closing and were analyzed in February 1977; samples for the rest of 1977 were returned to Boulder after the station opened in November and were analyzed in January and April 1978.

All flask samples were analyzed by a Lira infrared analyzer, Model 202, Serial No. 20719, manufactured by Mine Safety Appliance Company. In previous Summary Reports the results of the flask sample analyses were presented as monthly average CO_2 concentrations for each GMCC station. Since continuous analyzer data are available for all four stations in this report, the flask analyses are not reported separately.

The data from analyses of quasi-independent flask samples have been used to estimate "carrier gas effect" corrections for the four field station analyzers. These corrections can be used to normalize data to the baseline provided by the Boulder Lira Model 202 analyzer. "Carrier gas effect" denotes the error in CO_2 concentrations from infrared analyzers, resulting from the use of reference gas mixtures wherein proportions of N_2 and O_2 differ from natural air (Bischof, 1975; Pearman and Garratt, 1975; Pearman, 1977). The flask sample analyses also provide information to document performance variations in the Lira analyzer.

The CO_2 concentration of each flask sample has been compared to the corresponding mean hourly CO_2 concentration obtained with the continuous

analyzer. The concentration differences scatter over a small range (about 1 ppm) when plotted as a function of the analysis date. The means of these differences are quantitative estimates of concentration differences measured by the observation analyzers as compared to those from the Boulder Lira 202 analyzer. Preliminary estimates of these differences (usually referred to as "offsets" or the "carrier gas effect") for the four station analyzers, based on the first 10 mo of 1977 data, are tabulated as follows:

Station	Analyzer	Serial No.	Offset (ppm)*
BRW	UNOR-2	631521	-3.7
MLO	URAS-2	37626682	+1.0
SMO	URAS-2T	029	+1.6
SPO	URAS-2T	0101	+2.3

*Add or subtract this quantity as indicated to normalize to Boulder analyzer.

Three additional flask sampling programs operating during 1976 were continued through 1977. Pairs of air samples were collected, usually at weekly intervals, at Niwot Ridge, Colo., Key Biscayne, Fla., and Cape Kumukahi, Hawaii. Data for the three stations are listed in Table 7 and plotted in Fig. 8.

Table 7. 1977 Provisional Mean Monthly CO_2 Concentrations Determined From Flask Sampling*

	Cape Kumukahi, Hawaii		Key Biscayne, Fla.		Niwot Ridge, Colo.	
Month	Mean Conc.	No. of Samples	Mean Conc.	No. of Samples	Mean Conc.	No. of Samples
Jan	330.82	7	331.98	4	331.98	5
Feb	331.24	8	333.51	1	332.62	5
Mar	332.15	9	333.77	8	335.11	10
Apr	334.10	7	333.93	6	335.41	6
May	335.22	4	333.71	3	334.38	9
Jun	333.76	8	333.29	8	332.21	6
Jul	331.67	6	332.46	3	333.52	4
Aug	329.96	8	330.25	4	332.38	6
Sep	328.34	8	329.40	4	329.05	8
Oct	329.70	7	----	0	331.85	8
Nov	331.87	7	333.68	4	332.85	7
Dec	331.81	6	334.66	6	334.05	6

*Data are expressed in the Scripps 1959 Adjusted Index Scale.

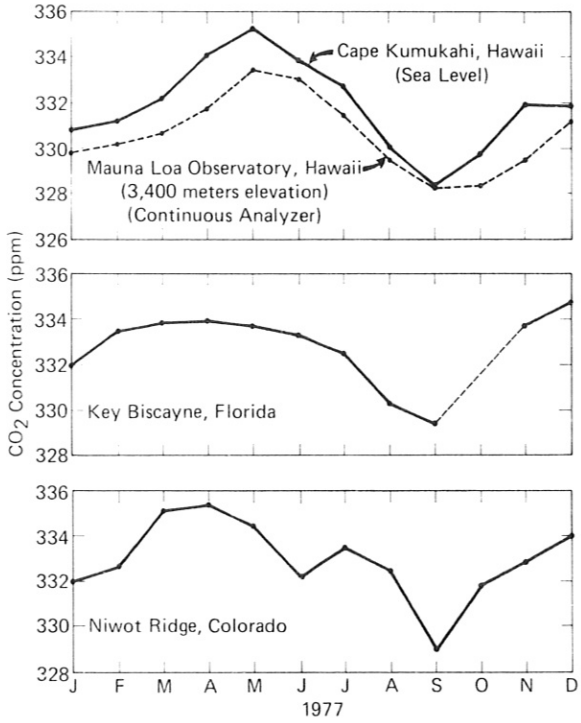


Figure 8. 1977 provisional CO_2 flask sampling monthly mean concentrations for Cape Kumukahi, Hawaii, Key Biscayne, Fla., and Niwot Ridge, Colo., and corresponding Mauna Loa Observatory continuous analyzer values. Data are expressed on the Scripps 1959 Adjusted Index Scale.

During 1977, flask samples were collected on 0 to 5 days at each site each month. The number of flasks exposed each month ranged from 0 to 10. For each sampling at least 2 flasks were exposed at the same time. Whenever the CO_2 concentration differed by no more than 0.8 ppm, both samples in a pair were accepted. In most instances, when the two samples in a pair differed by more than this limit, the sample with the lowest concentration was considered acceptable.

The Cape Kumukahi samples are contrasted with the Mauna Loa Observatory continuous analyzer record in Fig. 8. The MLO record has been corrected here for the "carrier gas effect" to remove the 1-ppm difference which occurs when the URAS-2 and Lira 202 are used to analyze the same air. The Cape Kumukahi samples, collected at sea level when winds were blowing from sea to land, represent the regional air mass regime with minimal island influence. The difference between samples at sea level and at MLO is approximately uniform except for the late-summer convergence to the same minimum in September. The continuous analyzer curve is determined by averaging 661 h of record per month (Table 5); the flask curve is based on only 3 to 5 instantaneous samples each month.

The Key Biscayne and Niwot Ridge data sets show a seasonal oscillation, and both lack the annual smoothness seen at Cape Kumukahi. The conspicuous summer "hump" in the Niwot Ridge curve may not represent the true mid-continental background condition. The Niwot Ridge samples are collected above the timberline near the Continental Divide without

regard to minimum wind speed and wind direction when an observer services meteorological instruments at a research site. The cleanest air, least affected by vegetation or urban pollution, is found when the wind is westerly. A preliminary scanning of the wind data for the 1977 sampling times suggests that the high summer values may be related to easterly and southerly winds at the sampling site. The Niwot Ridge (40°03' N) samples have a seasonal spread of almost 6.4 ppm whereas the Key Biscayne (25°41' N) seasonal difference is about 4.5 ppm. This variation of seasonal amplitude is consistent with the northern hemisphere latitudinal attenuation observed by Bolin and Keeling (1965).

3.1.3 Comparison of Mauna Loa Sampling Intakes

When the GMCC CO_2 MLO sampling program was begun in June 1974 three air intakes with air lines of 0.375-in aluminum tubing were installed. The three intakes were located as follows: A. 23 m above ground (the high tower), 65 m southwest of the analyzer; B. 6.6 m above ground, 328 m west (downhill) of the analyzer; C. 16 m above ground, 164 m southeast (uphill) of the analyzer. This layout was designed so that one intake would be upwind of the observatory during upslope and downslope wind regimes. Air from intakes A and B was sampled from 0800 to 2000 LST (1800 to 0600 CUT), the usual upslope wind flow period, whereas intakes A and C were used from 2000 to 0800 LST, the usual downslope wind flow period. During each half-hour, air was sampled from intake A for 10 min, from intake B or C for 10 min, and from two working reference gases for 5 min each. In July 1977, a 13 m-high, 8-cm diameter, polished aluminum sampling port was installed to replace the three external sampling lines (A, B, C). Two working reference gases now are each cycled through the system for 5 min each hour, and ambient air is drawn through the new port during the rest of the hour.

Before using the new sampling port, the effect that drawing air from different locations had on measured CO_2 concentrations was studied. First, CO_2 values were compared between intakes A and B, and A and C. All operational hours during January, February, and March 1977 were used except when the strip chart record indicated a varying trace (about 20% of the time). Concentrations within 0.05 ppm of each other were considered equal.

When data for intake A were compared with those for intake B, 25% of the samples showed no difference and 48% of the samples showed that the B values were greater than the A values. The average difference between A and B values was 0.038 ppm. The standard deviation was 0.132 ppm. When intakes A and C were compared, 39% of the samples showed no difference and 32% showed that C values were greater. The average difference between these air samples was 0.005 ppm. The standard deviation was ±0.104 ppm.

Before the sampling port was put into full use, concentrations from the sampling port were compared with those from the tower (intake A). One 10-min sample from the port and high tower was obtained each half

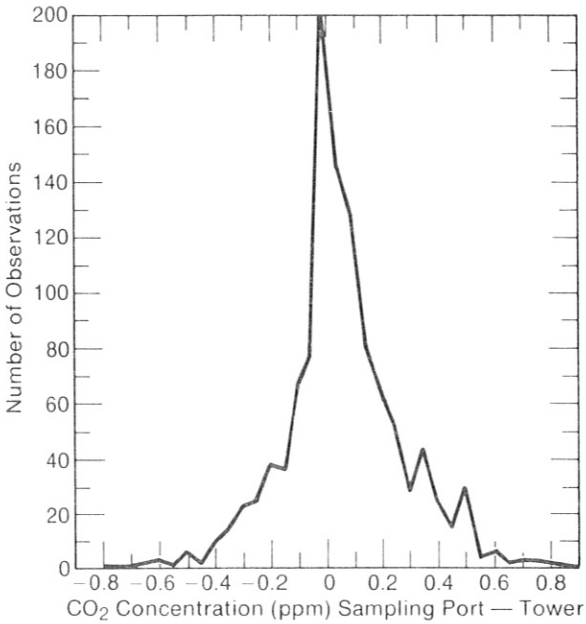


Figure 9. Distribution of differences between CO_2 concentrations from sampling port air samples and high tower air samples at Mauna Loa Observatory.

hour. Comparisons were made from August 27, 1977, through September 27, 1977. Valid, uncontaminated data were obtained for more than 85% of the hours (Fig. 9). No concentration differences were found between the two intakes 17% of the time, 56% of the samples showed that the sampling port values were greater, and 27% of the samples had greater tower values. The average difference between the two samples was 0.07 ppm. The standard deviation was 0.23 ppm. The large standard deviation resulted from a few differences exceeding 0.5. In almost three-fourths of all comparisons the sample differences were less than ±0.2 ppm.

The data from the sampling port and the tower were further compared by dividing them into times with upslope wind flow and times with downslope wind flow. For upslope flow 17% of the samples showed no difference, 48% showed the sampling port values to be greater, and 35% showed the high tower values greater. The average difference between the two samples was 0.04 ppm. During downslope flow, no difference occurred 17% of the time, the sampling port values were greater 66% of the time, and the high tower values were greater 17% of the time. The average difference between the two samples was 0.10 ppm.

The high tower-sampling port concentration differences were further stratified by time of day and wind speed (see Fig. 10). No relation was found between wind speed and concentration differences. Sampling port values were greater than high tower values from 0000 CUT through 1700 CUT whereas tower values were greater from 1800 CUT to 2300 CUT. The differences were small, averaging less than 0.1 ppm.

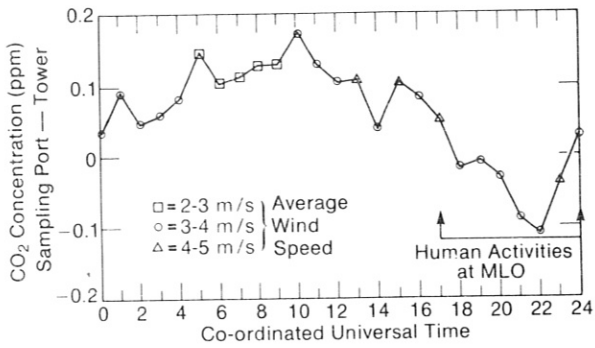


Figure 10. Average differences between CO_2 concentrations from sampling port values and high tower values at Mauna Loa Observatory as a function of time of day and wind speed.

In conclusion, results of the comparison between the sampling port and the high tower intake showed no large, systematic differences between the old and the new methods of sampling.

3.1.4 Analysis of CO_2 Variability at Mauna Loa

Data for the MLO CO_2 record may be contaminated by several sources causing values to be higher or lower than background values. During afternoon, upslope airflow often brings air to the observatory that has been exposed to vegetative photosynthesis at lower elevations; recorded concentrations of CO_2 are then typically lower than background values. At night, air typically flows downslope bringing any volcanic emissions from the summit to the observatory; recorded CO_2 concentrations are then higher than background values. Since the eruption of July 1975, such occurrences have been common. Table 8 lists the days during 1977 when excessively high concentrations due to gaseous volcanic venting were measured at night; such high CO_2 values were detected on 43% of all days. For May 1975 and May 1976, the average CO_2 concentration was obtained for each hour of the day; the average monthly diurnal variation is shown in Fig. 11. May 1975 shows a fairly steady nighttime record with lowest concentrations during mid- to late-afternoon. During May 1976, when volcanic gaseous venting increased, the nighttime values are more variable and the diurnal range is greater.

This section points out some variability that can occur in the MLO CO_2 record. For example, monthly averages at MLO determined from all measurements are typically several tenths of a ppm different from those using background periods only. This difference does not have a large effect on estimates of the long term CO_2 increase, but it is important for studies of processes affecting CO_2 concentrations on within-year time scales (Peterson, 1977). GMCC researchers are continuing to study the impact of contaminated, nonbackground air on background CO_2 records.

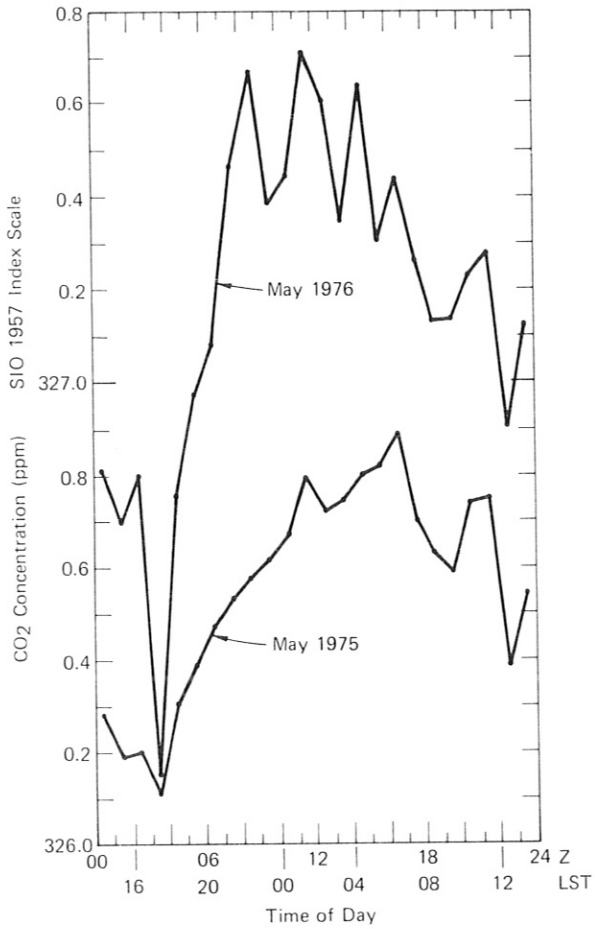


Figure 11. Average hourly CO_2 concentrations at Mauna Loa Observatory for May 1975 and May 1976.

Table 8. 1977 Dates of Short-Term Disturbances in CO_2 Record at MLO (1100-1900 CUT)

Month	Day of the Month																													Monthly Total
	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	
Jan			X	X	X						X				X	X	X	X					X			X	X			X	X	13
Feb		X	X	X	X	X		X	X	X	X	X			X						X	X			X		X	X				16
Mar				X						X	X	X	X				X	X	X		X	X			X	X	X	X			X	15
Apr		X	X	X	X		X	X	X	X	X	X					X						X	X	X		X		X	X		17
May			X	X	X	X		X	X							X	X	X	X	X	X	X								X		14
Jun				X	X		X	X			X				X																	6
Jul	X	X		X					X			X	X	X					X	X	X	X					X	X				13
Aug	X			X							X		X			X	X	X	X	X	X	X					X	X		X	X	15
Sep			X	X	X	X			X	X	X							X	X	X	X			X	X	X			X			15
Oct	X	X						X	X	X			X	X	X		X		X	X	X					X	X			X	X	16
Nov	X	X	X					X						X	X	X	X		X			X										10
Dec			X		X				X		X	X						X									X					7

3.2 Total Ozone

1977 was a productive year for the GMCC total ozone measurement program. Observations continued to be made at twelve stations of the U.S. Dobson spectrophotometer station network; twelve foreign Dobson instruments were electronically modernized and optically aligned and calibrated; an International Comparison of Dobson Ozone Spectrophotometers, sponsored by WMO, was conducted in Boulder.

3.2.1 Observations of Total Ozone

The 12 stations of the U.S. Dobson spectrophotometer station network are listed in Table 9. Table 10 gives provisional mean monthly total ozone amounts measured at these stations during 1977. All Table 10 values are based on intercalibrations of the various network Dobson spectrophotometers with U.S. standard Dobson instrument No. 83. Dobson No. 83 was designated as the World Primary Standard instrument for measuring total ozone by the WMO in 1976.

3.2.2 Reconditioning and Calibration of Dobson Spectrophotometers

The 1977 program to modernize and calibrate foreign Dobson spectrophotometers was conducted under the auspices of the Global Ozone Research and Monitoring Projects of the WMO. Table 11 lists the instruments included in the program. The U.S. Dobson spectrophotometer No. 87 has been operated by the Instituto Geofisico de Peru at Huancayo Observatory since 1964.

Table 9. U.S. Dobson Spectrophotometer Station Network, Including Cooperative Stations

Station	Period of Record (Mo-Day-Yr)	Instr. Serial No.	Agency
Bismarck, N. Dak.	010163-Present	33	NOAA-ARL
Caribou, Maine	010163-Present	34	NOAA-ARL
Tutuila Island, Samoa	121975-Present	42	NOAA-ARL
Tallahassee, Fla.	060273-Present	58	Fla. State Univ.
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, Antarctica	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	Instituto Geofisico de Peru

Table 10. 1977 Provisional Mean Monthly Total Ozone Amounts (matm-cm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bismarck, N. Dak.	398	380	421	376	359	348	331	324	303	308	317	371
Caribou, Maine	487	398	431	446	412	393	352	328	320	318	305	367
Tutuila Island, Samoa	256	253	253	254	253	254	254	253	249	254	267	263
Tallahassee, Fla.	306	328	300	342	353	336	323	310	298	292	271	277
Mauna Loa, Hawaii	245	250	274	294	293	298	279	270	257	251	239	235
Wallops Island, Va.	397	388	347	372	387	362	336	319	309	305	287	314
Barrow, Alaska	---	---	---	463	423	368	323	290	299	---	---	---
Nashville, Tenn.	367	369	330	371	364	347	345	324	312	313	288	304
Boulder, Colo.	346	362	392	364	352	328	321	309	294	288	284	309
White Sands, N. Mex.	316	330	329	356	352	321	323	313	295	286	267	277
Huancayo, Peru	247	251	249	246	248	247	247	255	258	260	257	259
Amundsen-Scott, Antarctica	305	281	---	---	---	---	---	---	---	260	386	368

New solid-state electronic systems were installed in all instruments in Table 11 except the Norwegian Nos. 8 and 14, which were modernized early in 1977 at the University of Oslo, Norway. After the alignment of optical components was checked and adjusted the instruments were calibrated by direct comparison with World Standard Dobson instrument No. 83. The Dobson instrument No. 83 was transported to Argentina, Brazil, and Peru to calibrate the South American instruments; the remaining spectrophotometers (except Spanish instrument No. 120) were calibrated in Boulder, Colo. Since calibration problems were found for instrument No. 120, during a trip to Spain late in 1977, a recommendation was made to WMO to transport the instrument to the GMCC Laboratory in Boulder for a complete optical re-alignment and calibraton.

3.2.3 WMO International Dobson Spectrophotometer Comparisons

In a continuing program within the WMO Global Ozone Monitoring and Research Project to upgrade the quality of world-wide total ozone observations, comparisons of Dobson ozone spectrophotometers were held in Boulder, Colo., from July 25 to August 20, 1977. The comparisons were made at the NOAA, Air Resources Laboratories (GMCC Program), by W. Komhyr and assistants R. Grass and R. Leonard. Participants and visitors at the comparisons are shown in Fig. 12.

Countries, instruments, and scientists that participated in the comparisons are listed in Table 12. A. Losiowa of the Polish Academy of Sciences, convener of the international Dobson spectrophotometer comparisons in Belsk, Poland, June 24, to July 6, 1974, and C. Walshaw, Secretary of the International Ozone Commission, provided valuable assistance. Distinguished visitors were R. Bojkov, Chief, WMO Atmospheric Sciences Division; H. Dütsch, President, International Ozone

Table 11. Instruments Modernized and Calibrated During 1977

Country	Inst. No.
Peru	87
Argentina	97
Argentina	99
Brazil	114
Norway	8
Norway	14
Norway	56
Iceland	50
Denmark	92
Egypt	96
German Democratic Republic	71
Australia	105
Spain	120

Commission; J. London, member of the International Ozone Commission, and L. Machta, Director, NOAA, Air Resources Laboratories.

The reference standard spectrophotometer for the instrument comparisons was U.S. Dobson instrument No. 83 designated by the WMO as the primary reference standard instrument for total ozone measurements. This instrument was calibrated on an absolute scale at Mauna Loa Observatory, Hawaii, in 1972 and 1976, and was used as the reference standard spectrophotometer during the 1974 Belsk instrument comparisons.

An error in sign had been made in applying corrections to the N-tables of instrument No. 83 deduced during the 1972 Mauna Loa Observatory calibration of the instrument. At the time of the Belsk, Poland, spectrophotometer comparisons, corrections necessary for instrument No. 83 N-values (N-values are related to radiation intensities at observation wavelengths) were as follows:

To N_A values add 0.028.

To N_C values add 0.023.

To N_D values add 0.031.

To N_{AD} values add -0.003.

To N_{CD} values add -0.008.

For X_{AD} (measurements of direct-sun intensities at wavelengths A and D) observations, which are the primary observations, and for an ozone amount of 0.300 atm-cm, the instrument No. 83 N_{AD} calibration error amounted to errors in ozone of 0.67%, 0.33%, and 0.23% at μ (a measure of the ozone layer relative optical air mass) values of 1, 2, and 3, respectively.

Figure 12. Participants and visitors at the WMO International Comparison of Dobson Ozone Spectrophotometers, Boulder, Colo., August 1977. From left to right: A. Chopra, C. Walshaw, W. Komhyr, J. Convery, A. Losiowa, J. London, H. Dütsch, R. Grass, R. Basher, R. Olofson, R. Bojkov, N. Cosgriff, R. Kulkarni, L. Machta, S. Oltmans, H. Muramatsu, K. Grasnick, G. Hassan, and A. Asbridge.

During the intercomparisons, modern electro-mechanical circuitry developed at NOAA was installed into three spectrophotometers: instruments No. 71, 96, and 105. Before final calibration, the optical alignment of these instruments was thoroughly checked and corrected as needed. Most of this work was performed by R. Grass, assisted by A. Asbridge and R. Olofson of the Canadian Atmospheric Environment Service.

When it arrived in Boulder, each spectrophotometer was intercalibrated one or more times with primary reference standard instrument No. 83 so that N-value corrections might be determined. Such corrections can be used to correct ozone data from past observations. Although weather and sky conditions were not ideal for spectrophotometer observations of direct sun during most comparisons, the sky cleared on the morning of August 20 and an excellent set of calibration data were obtained. Subsequent analysis of all data indicated that ideal observing conditions are not required for intercalibrating spectrophotometers; high quality results can be obtained from simultaneous spectrophotometer observations of direct sun when the sky is hazy or when the sun is obscured by clouds.

Table 12. International Dobson Spectrophotometer Comparison Participants

Country	Instr. No.	Participant
Australia	105	R. Kulkarni
Canada	77	R. Olofson/A. Asbridge
Egypt	96	G. Hassan
German Democratic Republic	71	K. Grasnick
India	112	A. Chopra
Japan	116	H. Muramatsu
United Kingdom	41	J. Convery
United States	83	W. Komhyr/R. Grass

The results of the initial spectrophotometer calibrations are summarized in Table 13. The table includes N-value corrections for instruments, as well as percent corrections to X_{AD} values as a function of μ for an ozone amount of 0.300 atm-cm. Data in the last column of Table 13 indicate that, on the average, corrections needed for the primary X_{AD} direct-sun data amounted to about 1% or less for four instruments, about 2½% for two instruments, and about 6% for one instrument. These corrections represent a significant improvement over similar data obtained in 1974 at the Belsk, Poland, instrument comparisons, and attest to the value of conducting periodic international comparisons of Dobson spectrophotometers.

Preliminary results of the July 25 to August 20, 1977, WMO international comparison of Dobson spectrophotometers were available to participants before their departure from Boulder. Final results were obtained after observational data errors were eliminated and a newly

Table 13. Corrections to N and X_{AD} Values for Spectrophotometers Using Instrument No. 83 as Reference Instrument

Instr. No.	N-Value Corrections					% Correction to X_{AD} Values for X_{AD} = 0.300 atm-cm			
	ΔN_A	ΔN_C	ΔN_D	ΔN_{AD}	ΔN_{CD}	μ=1	μ=2	μ=3	Mean
105	0.0069	-0.0130	-0.0119	0.0188	-0.0011	4.50	2.27	1.50	2.76
77	0.0373	0.0275	0.0450	-0.0077	-0.0175	-1.83	-0.93	-0.60	-1.12
96	-0.0871	-0.0536	-0.0691	-0.0180	0.0155	-4.33	-2.17	-1.43	-2.64
71	-0.0488	-0.0721	-0.0920	0.0432	0.0199	10.37	5.20	3.46	6.34
112	0.0286	0.0315	0.0270	0.0016	0.0045	0.36	0.20	0.13	0.23
116	0.0025	0.0029	0.0069	-0.0044	-0.0040	-1.07	-0.53	-0.33	-0.64
41	0.0378	0.0335	0.0308	0.0070	0.0027	1.70	0.83	0.57	1.03

devised data reduction computer program was refined to yield calibration information as a function of μ. The final data indicated that Dobson instruments 77 and 116 exhibit less internal light scattering at A wavelengths than instruments 41, 83, 105, and 112. Light scattering effects within instruments 71 and 96 are most pronounced. Within the μ range 1.15 to 3.2, however, all calibrated instruments yield average X_{AD} total ozone values that agree to within ±1% or better.

The Dobson instruments listed in Table 12 have been designated by the WMO as regional secondary reference standard spectrophotometers. The principal function of these instruments is to calibrate field spectrophotometers within their regions. The WMO urges that the calibrating of field spectrophotometers proceed as quickly as possible so that Dobson instruments throughout the world can yield comparable data for research purposes.

3.3 Surface Ozone

A program of side-by-side measurements of surface ozone using the ECC oxidant meter and Dasibi ozone photometer continued through 1977. Although no major changes were made in measuring instruments, the method of bringing the air sample from outside the observatory building to the sensing instruments was changed. At the four baseline observatories the air is now drawn into the building by using a common gas sampling stack (common to all the gases). The change to the new sampling system caused leaks and ozone destruction that resulted in some data loss. The dates for changes to the new system are as follows:

Barrow, Alaska	May 5, 1977
Mauna Loa, Hawaii	Sept. 21, 1977
Samoa	Aug. 15, 1977
South Pole	Jan. 23, 1975
	Jan. 20, 1977 (stack in new CAF).

The 1976 GMCC Summary Report noted a diurnal variation of surface ozone concentration in winter and spring at Samoa. The variation may have been real or a result of the sampling site above the observatory building. In August sampling began from the new stack at the remote sampling building nearer the Point. Data for 4 months seem to confirm the diurnal variation. More measurements are needed to see if the sampling site is the cause of the diurnal effect.

In previous Summary Reports surface ozone data were calculated on the assumption that the instruments were self-calibrating; i.e., that the basic instrument equations could be used to calculate the ozone amount for the ECC and Dasibi ozone meters. In 1976 three ECC sensors were compared with the NBS-maintained UV photometer, and the results were briefly mentioned in the GMCC Summary Report 1976. A more complete analysis is presented here.

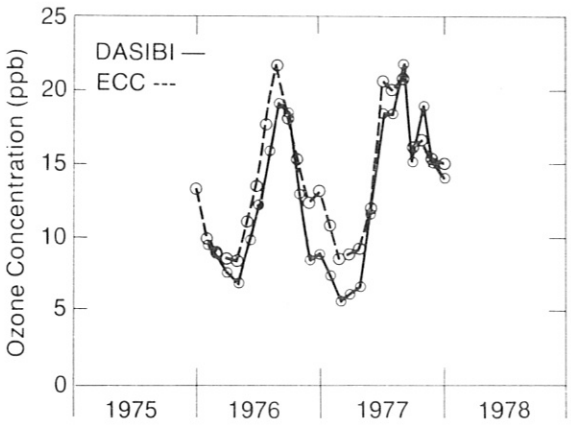


Figure 13. Adjusted monthly mean surface ozone concentrations at Samoa measured with ECC and with Dasibi meters for 1975-1978.

The measured ozone amount for the ECC meter was found to vary with sensing solution concentration. During 1977, ECC measurements have been made using a 1.5% solution of potassium iodide (KI); such a solution gives readings that are about 8% too high compared to the NBS standard. A 1.0% solution of KI gives results within 0.1 percent of the NBS value. The linear regression relationships based on the comparisons using the two solutions are given as follows:

(1) For a 1.5% solution, NBS standard = 2.4 + (0.921 ± 0.013) ECC;

(2) For a 1.0% solution, NBS standard = 1.73 + (0.999 ± 0.012) ECC.

Using these comparisons and comparison of the ECC sensors with other operating instruments in the GMCC program, the data through 1977 are being adjusted to the scale represented by the NBS standard. This reprocessing has been completed for the Samoa ECC and Dasibi meter observations, and the monthly means are shown in Fig. 13.

3.4 Halocarbons

3.4.1 Operations

1977 changes in the halocarbon program include the following: (1) conversion from evacuated flasks to pressurized flasks, (2) continued measurement of trichlorofluoromethane (F-11) with the addition of dichlorodifluoromethane (F-12) and nitrous oxide (N_2O) measurements, and (3) use of reference gases for daily gas chromatograph calibrations. This section describes these changes more fully and presents the 1977 data.

Station Sampling

In January 1977, a dual-cylinder pump-up system was installed at the South Pole. The system consists of a 7-μ filter, a metal bellows

pump, a pressure relief valve, and a tee dividing the air flow between two cylinders. A short section of stainless steel tubing connects the pump to one port of the station's gas sampling manifold and stack. Four pairs of flasks were pressurized in late January and early February 1977, and then shipped to Boulder for analysis before the winter station closing. One pair of flasks was then exposed each month through November; they were returned to Boulder in December. Two pairs of flasks were pumped in December.

Similar pump-up systems were installed at the other baseline stations in July 1977. Sample pairs were pumped each week along with the normal exposure of an evacuated flask through November when the evacuated flask sampling program was discontinued. Niwot Ridge, Colo., samples consisted of evacuated cylinder pairs exposed each week throughout the year.

New Chemical Measurements

When a 10' x 3/16" Porasil B column was installed in late April, gas chromatographic measurements of F-12 could be taken in addition to those for F-11. In late June, a 3' x ¼" Porasil A column was installed in the gas chromatograph. Then N_2O, as well as F-12, could be separated, but resolution between the air peak and N_2O was not very good. Finally in late July, a 4' x 1/8" Porasil A column was installed that gave good separation of F-12 and N_2O from the air peak. This column was used during the rest of the year with periodic reconditioning.

Gas Chromatograph Calibrations

Until March 1977, calibration of the Boulder chromatograph was based on a limited number of gas sample intercomparisons with the ARL/NOAA Idaho Falls Field Research Office chromatograph.

When the Idaho Falls chromatograph was first set up, detector efficiency factors were assigned to it based on operating condition research by J. Lovelock. These efficiency factors were considered constant because of equipment long-term stability. Gas samples were analyzed before and after a change in the gas chromatograph operating conditions. New efficiency factors were then determined and transferred to the Boulder equipment by sample comparison.

As experience with the chromatograph increased, equipment instabilities were discovered, and a static dilution system was built for routine calibration. Initial work with the apparatus showed that concentrations on the order of parts per trillion could not be reproduced.

Until a mixing gas standard system could be developed for low concentrations, high pressure cylinders, specially cleaned and prepared, were pumped with local air to serve as working reference tanks. In late February, the first tanks were filled at Niwot Ridge, Colo., and ana-

lyzed. One tank, 3072, was chosen to be the daily working gas; a second tank, 3078, was later chosen to be a long-term reference. In the sample analysis scheme using reference gases, tank 3072 reference gas is analyzed daily before and after every two chromatographic analyses of an unknown sample. On a 3- to 6-mo basis, tank 3078 is analyzed by comparing it to tank 3072.

In December 1977, tanks 3072 and 3078 were compared to R. Rasmussen's Standard 006 at the Oregon Graduate Center in Beaverton, Ore. Tank concentrations for N_2O, F-12, and F-11 were determined (see Section 6.9 for discussion of this intercomparison). Station sample concentrations of these constituents determined by comparison to tank 3072 have been adjusted to the Oregon Graduate Center scale.

3.4.2 Data

1977 provisional F-11, F-12, and N_2O data are presented in Table 14 for the four observatories and Niwot Ridge near Boulder. 1977 F-11 data for evacuated flask and pressurized flask sampling are shown in Fig. 14. All available GMCC F-11 measurements from evacuated flask sampling are compared in Fig. 15. Figures 16 and 17 show F-12 and N_2O data plots, respectively, for 1977. Although similar data exist for the Barrow, MLO, and Samoa stations from evacuated flask sample collections and analyses, they are not included because a high degree of data variability resulted from sampling problems.

Data in this report should be regarded as provisonal since they may contain errors resulting from sample collection problems, analyzer malfunctions, and possibly reference gas calibration drifts. Furthermore, the data have not been referenced to dry air. Data quality nevertheless has improved significantly since implementation of the use of calibration gases in sample analyses. Because of variability in the 1977 and early 1978 (not shown) F-12 data, a longer record is needed for definitive information about growth rates and latitudinal gradients. However, as of December 31, 1977, the annual growth rate of F-11 appears to be about 8% per year, computed from measurements in 1977 and early 1978. This rate is approximately one-half the growth rate measured earlier in the 1970's, probably reflecting the lower rates of F-11 input into the atmosphere compared with the exponential rate of input increase before 1974. The data also suggest that the latitudinal gradient in F-11 is significantly smaller than reported earlier. This result implies that the lifetime of F-11 in the atmosphere is probably more than 50 yr and that the potential threat of destruction of stratospheric ozone by F-11 is probably real.

N_2O data show considerably less scatter than the F-11 measurements and indicate that atmospheric N_2O concentrations are remaining essentially constant. The biological sources of N_2O are probably sufficiently large to mask increases in atmospheric N_2O concentrations arising from human activities such as increased use of fertiliziers.

Table 14. 1977 Provisional Halocarbon Data From Baseline Stations

Station	Date	F-11 Evac. Conc.	F-11 Evac. Cyl. S.D.	F-11 Pres. Conc.	F-11 Pres. Cyl. S.D.	F-12 Evac. Conc.	F-12 Evac. Cyl. S.D.	F-12 Pres. Conc.	F-12 Pres. Cyl. S.D.	N_2O Evac. Conc.	N_2O Evac. Cyl. S.D.	N_2O Pres. Conc.	N_2O Pres. Cyl. S.D.
Barrow													
	Jan 6	177	1										
	12	198	1										
	26	166	-										
	Feb 15	166	-										
	22	172	1										
	Mar 11	163	-										
	19	164	1										
	24	164	0										
	Apr 8	165	4										
	13	167	2										
	20	L	-										
	May 2	172	3			551	6						
	10	L	-			L	-						
	24	182	1			2630	13						
	Jun 2	160	2			311	1						
	9	L	-			L	-						
	16	166	1			367	-						
	Jul												
	Aug 3	182	1	156	4	3172	10	278	12	393	3	344	7
	8	174	6	158	2	426	1	343	17	381	11	334	8
	17	178	4	154	2	377	14	290	9	408	8	327	8
	Sep 4	174	4	157	4	1008	11	291	11	373	6	338	4
	11	L	-	157	4	L	-	285	7	L	-	332	13
	17	168	2	163	3	434	3	294	12	331	14	334	11
	28	L	-	158	5	L	-	303	10	L	-	328	5
	Oct 8	178	5	163	5	365	3	295	10	344	1	336	4
	11	169	5	167	3	527	41	305	15	327	8	329	4
	20	202	2	166	3	684	35	321	15	321	14	338	4
	Nov 2	173	3	164	2	463	2	317	8	331	5	335	4
	9	172	4	169	4	641	8	307	9	337	5	334	5
	14	L	-	166	3	L	-	321	4	L	-	332	3
	26	184	5	167	2	1167	23	379	14	330	-	339	10
	Dec 11			171	1			329	6			335	9
	17			170	4			345	2			338	2
	29			168	5			325	6			340	3
Mauna Loa													
	Jan 6	156	2										
	11	158	1										
	19	163	2										
	24	165	1										
	Feb 4	158	1										
	14	156	1										
	23	161	-										
	28	178	0										
	Mar 9	159	2										
	16	151	-										
	21	164	0										
	Apr 4	150	2										
	13	148	2										
	19	154	3										
	26	171	2										

Table 14. 1977 Provisional Halocarbon Data From Baseline Stations (continued)

Station	Date	F-11 Evac. Cyl. Conc.	F-11 Evac. Cyl. S.D.	F-11 Pres. Cyl. Conc.	F-11 Pres. Cyl. S.D.	F-12 Evac. Cyl. Conc.	F-12 Evac. Cyl. S.D.	F-12 Pres. Cyl. Conc.	F-12 Pres. Cyl. S.D.	N_2O Evac. Cyl. Conc.	N_2O Evac. Cyl. S.D.	N_2O Pres. Cyl. Conc.	N_2O Pres. Cyl. S.D.
Mauna Loa (continued)													
	May 2	154	2			281	9						
	11	148	5			258	6						
	16	178	4			358	2						
	24	154	1			293	3						
	31	153	2			262	2						
	Jun 6	168	2			310	7						
	16	150	2			343	5						
	22	155	2			267	7			342	8		
	30	167	1			299	17			368	3		
	Jul 6	165	4			317	5			349	8		
	13	156	-			275	3			361	8		
	19	154	4			307	7			347	7		
	27	157	1			283	3			358	2		
	Aug 3	160	2			977	14			353	2		
	11	160	5			310	7			338	16		
	25			152	4			305	11			352	9
	30	169	1			293	2			366	6		
	Sep 6	158	2			273	2			344	2		
	15	166	7	153	5	329	4	265	6	363	11	334	3
	20	170	3	154	4	317	4	277	14	422	18	337	10
	28	161	3	157	6	272	2	269	5	337	3	332	2
	Oct 6	165	1	155	5	335	3	287	9	346	6	328	5
	13	158	9	147	2	300	3	300	25	382	7	333	3
	19	160	5	155	2	829	-	275	3	319	16	327	5
	Nov 4	161	4	158	4	349	5	282	4	359	3	337	11
	10	158	5	152	3	309	7	274	3	352	4	329	9
	17	164	7	155	5	281	3	281	10	338	3	330	2
	24	156	3	153	1	333	4	269	3	336	6	329	6
	Dec 8			157	4			288	4			328	10
	15			154	6			288	2			331	4
	22			157	3			284	10			336	2
	29			156	3			278	3			334	6
Samoa													
	Jan 6	147	1										
	13	156	1										
	23	143	2										
	27	150	0										
	Feb 3	157	2										
	12	146	1										
	18	153	0										
	26	192	2										
	Mar 8	136	1										
	11	140	-										
	17	154	2										
	Apr 1	135	2										
	8	142	3										
	19	150	2										
	30	152	2			280	4						
	May 5	151	4			293	6						
	14	141	2			250	6						
	19	142	5			266	7						
	26	145	4			299	8						

Table 14. 1977 Provisional Halocarbon Data From Baseline Stations (continued)

Station	Date	F-11 Evac. Cyl. Conc.	F-11 Evac. Cyl. S.D.	F-11 Pres. Cyl. Conc.	F-11 Pres. Cyl. S.D.	F-12 Evac. Cyl. Conc.	F-12 Evac. Cyl. S.D.	F-12 Pres. Cyl. Conc.	F-12 Pres. Cyl. S.D.	N_2O Evac. Cyl. Conc.	N_2O Evac. Cyl. S.D.	N_2O Pres. Cyl. Conc.	N_2O Pres. Cyl. S.D.
Samoa (continued)													
	Jun 5	144	2			247	1						
	10	152	1			275	3						
	18	144	2			282	1			366	-		
	23	151	8			261	6			367	14		
	29	147	3			271	5			371	2		
	Jul 14	143	-			255	7			365	11		
	27	151	1			252	1			338	3		
	Aug 4	148	2			262	3			350	12		
	12	154	6	140	3	259	3	253	7	350	8	324	11
	19	160	5	144	0	340	10	249	5	364	5	345	13
	25	150	1	142	0	272	1	250	6	350	17	380	26
	31	150	3	137	0	257	3	247	4	342	1	326	5
	Sep 14	147	4	141	5	300	1	246	3	343	8	343	9
	21	142	3	141	0	263	5	249	3	350	4	328	12
	28	160	1	143	2	266	4	247	4	344	5	334	6
	Oct 7	147	5	145	9	298	4	254	14	336	4	337	7
	16	149	3	142	4	287	4	251	6	347	2	326	6
	20	167	3	144	5	278	3	250	4	251	2	331	6
	29	147	2	140	7	311	4	256	10	334	3	314	8
	Nov 3	139	0	140	4	279	2	256	2	247	2	328	6
	10	171	3	139	4	276	3	247	3	354	14	330	8
	17	145	2	143	6	297	3	248	3	376	6	326	2
	24	146	1	146	5	291	1	248	1	354	7	324	5
	Dec 3			141	5			252	5			327	7
	7			139	5			260	6			336	12
	15			139	3			258	5			323	12
	30			145	3			258	4			324	8
Niwot Ridge													
	Jan 7	161	1										
	17	165	3										
	27	160	1										
	Feb 3	159	2										
	9	208	1										
	23	184	4										
	Mar 7	248	9										
	9	147	-										
	18	156	2										
	25	150	2										
	30	157	-										
	Apr 7	L	-										
	13	156	2										
	22	216	0										
	27	155	2										
	May 5	184	5			332	16						
	10			152	2								
	12	151	2			264	4						
	17			169	2								
	19	150	-	157	1	267	3						
	24			151	1								
	26	166	3			302	12						
	31	150	5			266	3						

Table 14. 1977 Provisional Halocarbon Data From Baseline Stations (continued)

Station	Date	F-11 Evac. Cyl. Conc.	F-11 Evac. Cyl. S.D.	F-11 Pres. Cyl. Conc.	F-11 Pres. Cyl. S.D.	F-12 Evac. Cyl. Conc.	F-12 Evac. Cyl. S.D.	F-12 Pres. Cyl. Conc.	F-12 Pres. Cyl. S.D.	N_2O Evac. Cyl. Conc.	N_2O Evac. Cyl. S.D.	N_2O Pres. Cyl. Conc.	N_2O Pres. Cyl. S.D.
Niwot Ridge (continued)													
	Jun 1			155	2								
	8	152	1			324	0						
	15	149	0			285	22			332	8		
	21	163	5			270	4			325	2		
	28	L	-			L	-			L	-		
	Jul 13	152	5			271	3			323	7		
	19	151	3			281	-			335	10		
	27	L	-			L	-			L	-		
	Aug 2	156	4			281	5			330	10		
	10	156	3			270	5			333	3		
	17	L	-			L	-			L	-		
	25	156	5			295	20			327	9		
	Sep 1	154	2			271	2			328	2		
	15	156	6			290	10			330	5		
	22	154	0			309	3			333	6		
	29	155	7			290	16			329	6		
	Oct 8	160	6			319	15			332	9		
	13	161	4			319	23			331	3		
	23	160	3			332	26			332	4		
	27	164	4			302	10			360	8		
	Nov 3	157	4			307	17			333	3		
	11	160	5			292	17			331	9		
	21	159	5			297	10			333	3		
	29	155	8			303	11			331	6		
	Dec 7	168	8			383	21			344	9		
	17	168	3			291	4			343	5		
	31	160	0			308	1			340	5		
South Pole													
	Jan 26			145	3			251	5			346	7
	Feb 4			141	7			240	1			346	4
	7			135	5			245	14			344	3
	10			131	-			244	2			342	9
	Mar 14			73	4			229	0			326	8
	Apr 14			79	3			235	1			343	8
	May 13			L	-			L	-			L	-
	Jun 13			ND	-			241	2			317	5
	Jul 13			124	-			240	-			336	-
	Aug 15			L	-			L	-			L	-
	Sep 13			L	-			L	-			L	-
	Oct 12			130	8			246	-			326	-
	Nov 14			L	-			L	-			L	-
	Dec 1			154	4			263	0			337	1
	18			L	-			L	-			L	-

Note: L = sample leaked.

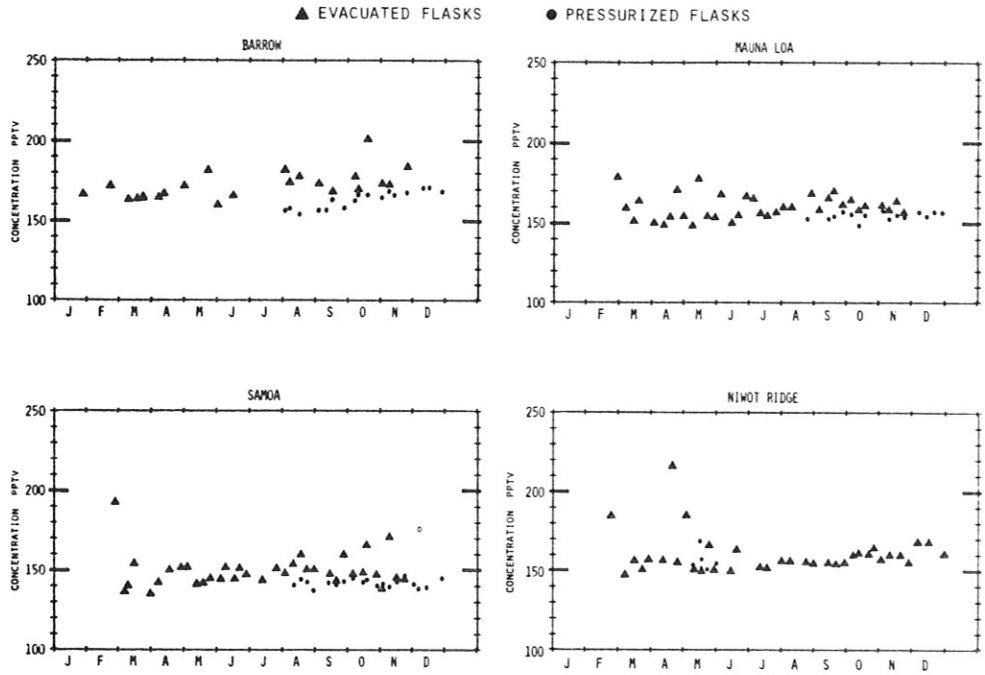


Figure 14. 1977 provisional F-11 data from evacuated and pressurized flask sampling for Barrow, Mauna Loa, and Samoa Observatories and for Niwot Ridge, Colo.

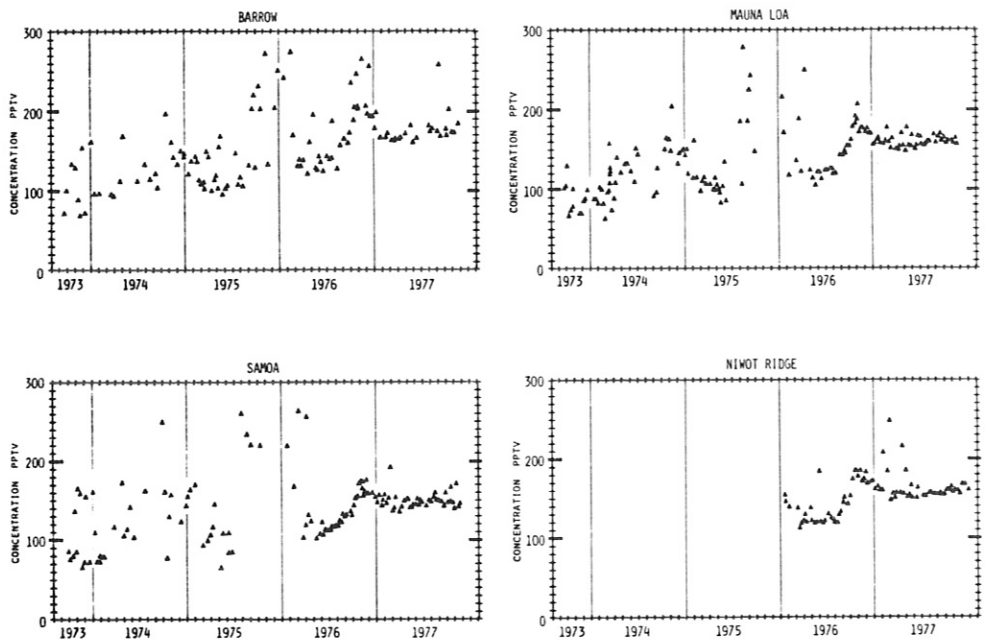


Figure 15. All GMCC F-11 measurements from evacuated flask sampling for Barrow, Mauna Loa, and Samoa Observatories and Niwot Ridge, Colo.

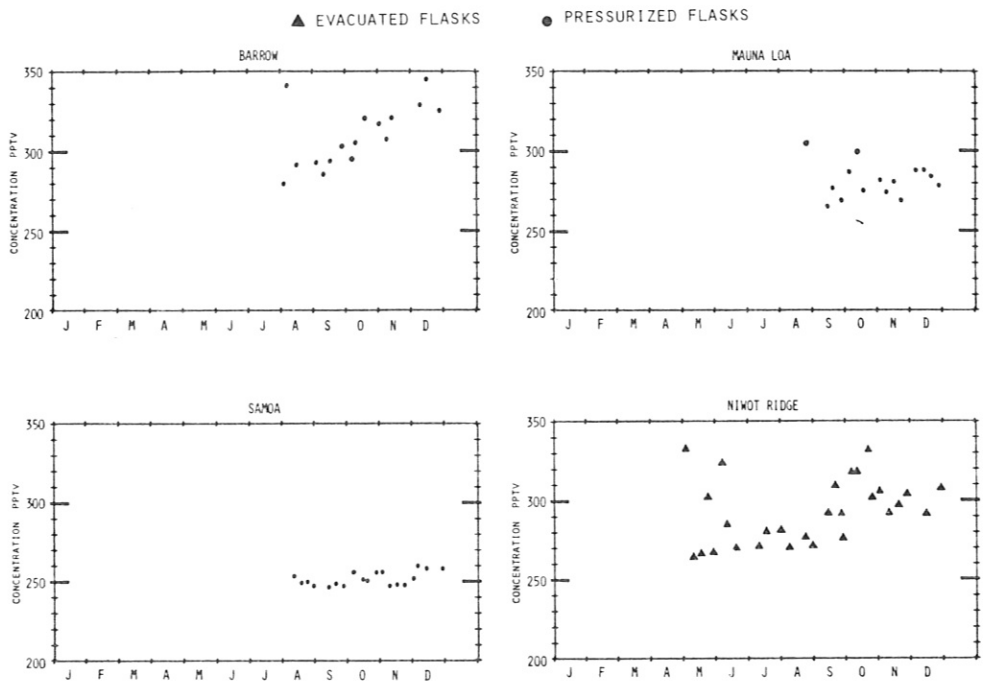


Figure 16. 1977 provisional F-12 data from evacuated and pressurized flask sampling for Barrow, Mauna Loa, and Samoa Observatories and Niwot Ridge, Colo.

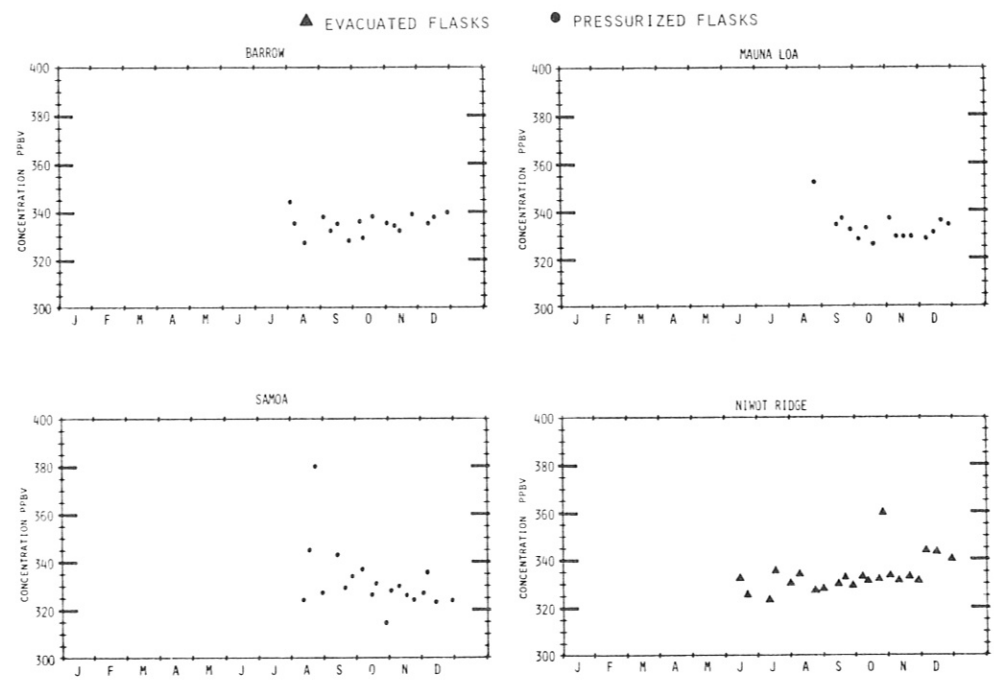


Figure 17. 1977 provisional N_2O data from evacuated and pressurized flask sampling for Barrow, Mauna Loa, and Samoa Observatories and Niwot Ridge, Colo.

3.5 Stratospheric Monitoring Using Lidar

3.5.1 Mauna Loa Lidar System

The Mauna Loa lidar system consists of a high-powered ruby laser and semiautomatic data processing facilities (see Fegley et al., 1978a). Except for short outages, a continuous record of stratospheric soundings exists from April 1973 through 1977.

During 1977, the eruption of Nyiragongo Volcano in Zaire, Africa (Fegley, 1977, 1978a) injected particles up to the tropopause. The volcanic dust cloud near the tropopause was detected by lidar measurements at MLO. An example of a lidar-determined vertical profile of aerosol backscatter at MLO is shown in Fig. 18.

The 1976 data consisting of aerosol backscatter coefficients at 1-km intervals throughout the lower stratosphere from Mauna Loa were made ready for publication during 1977 (Fegley, 1978b). The data show the continuation of the stratospheric cleansing following the eruption of De Fuego Volcano in late 1974 (Fegley and Ellis, 1975a, 1975b).

Hardware problems with the MLO laser were the following:

1. After detecting the Nyiragongo cloud, the laser flashlamp exploded, damaging the laser head.

2. After the laser was repaired, the Biomation Transient Digitizer was found to be faulty. During April and May, data were taken on Polaroid film, a less accurate collection method.

3. In February 1978, the flashlamp failed again, and the lidar was down for several weeks.

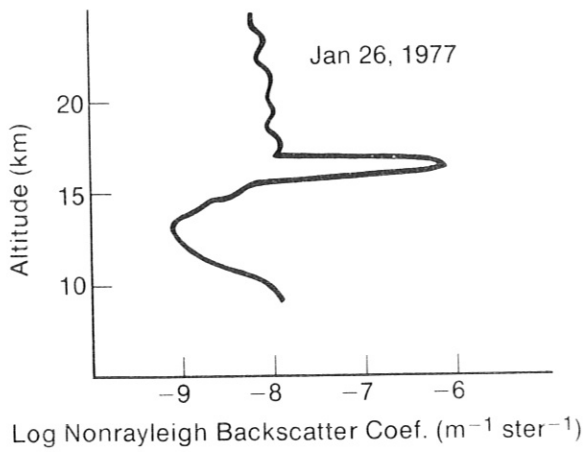


Figure 18. Non-Rayleigh (aerosol) backscatter coefficient vs. altitude measured by lidar at Mauna Loa on January 26, 1977.

3.5.2 Barrow Lidar Development

The Barrow lidar system was made operational at Boulder during 1977 in a special skylight-equipped room on the top floor of PSRB-3, and regular weekly observations were begun during the fall. The characteristics of the Barrow lidar system are as follows:

Pulse Energy	1.5 J
Pulse Duration	0.6 μs
Primary Wavelength (variable)	630 nm
Pulse Rate	30 pulses min^{-1}
Peak Power	2.5 megaW
Receiver Aperture (diameter) (plastic Fresnel lens)	40 cm
Photomultiplier	EMI 9658B
Digitizer	Biomation 805
Processor	NOVA 3/4 with CAMAC interface.

The lidar was designed to be semi-automatic to minimize operator errors. A block diagram of the lidar control system is shown in Fig. 19.

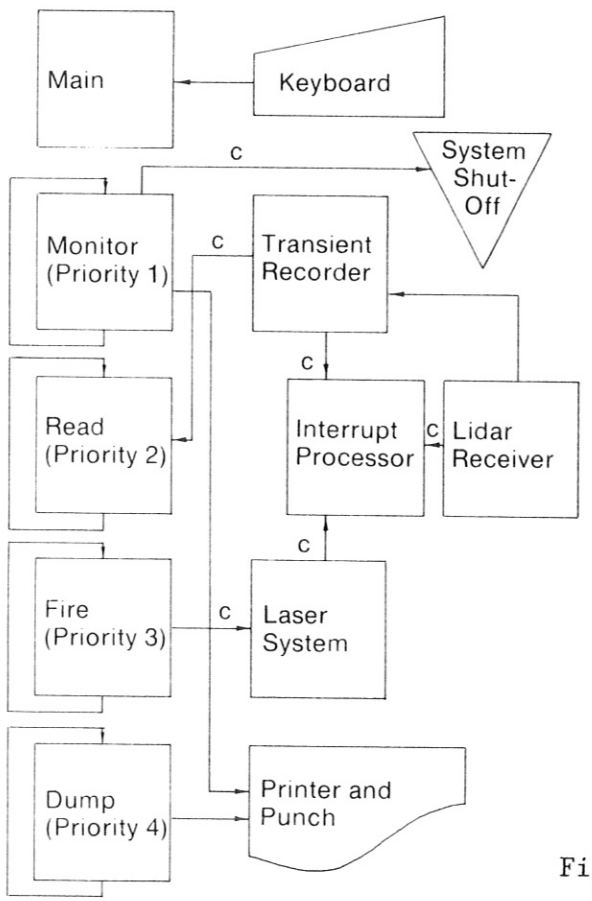


Figure 19. Block diagram of Barrow lidar control system.

The NOVA computer, including all components shown in Fig. 19 except recorder, receiver, and laser, has four independent programs which run simultaneously. The MONITOR program (highest priority) monitors vital system functions such as water cooling, dye flow in the laser, high-voltage, etc. Failure of any of these functions causes the system to shut down immediately, avoiding destruction of expensive system components. The READ program (2nd priority) transfers the data from the digitizer to the computer as each atmospheric lidar return signal is received and stored. It also averages the returns to reduce noise. The FIRE (3rd priority) program fires the lidar system at an operator preset interval. The DUMP program (lowest priority) transfers the analyzed results to the teletype printer at an operator preset interval. The data are punched onto paper tape for archiving. The typical dump period is from 20 min to 6 h. An INTERRUPT program services each piece of hardware as needed.

Most interfacing between hardware components uses the internationally standardized CAMAC system (Costrell, 1973). These interconnections are denoted by a "C" in Fig. 19. CAMAC minimizes hardware engineering when developing a system and allows rapid trouble-shooting and module-swapping in the field for easy repair. This may be the first application of CAMAC to a lidar system.

Some engineering and field hardening remains to be done on the lidar system. The site at Barrow must be prepared before the system is shipped.

3.5.3 Data Analysis

The major improvement in computer programming during 1977 is the storage of lidar data on magnetic tape during and after processing. The data, which come to Boulder from the MLO and BRW (at Boulder) lidar systems, are simultaneously processed from paper tape and stored on magnetic tape by year. The magnetic tape provides an input file of lidar data that will be rapidly available. After initial processing, the lidar results are transferred to a second tape reel. This reel forms a data collection, by year, which can be archived. A final product of the analysis program is a printed page of data for each stratospheric profile, that will be published as a NOAA technical report.

In a second improvement to the lidar analysis program, rawinsonde data from the Hilo and Denver NWS stations can be used in the program so that molecular density can be calculated at each height without using a model atmosphere. This is especially important at Boulder where deviations from the U.S. standard atmosphere can be large. Since the aerosol backscatter is calculated by subtracting the Rayleigh backscatter from the total, any error in the Rayleigh backscatter can distort the aerosol component. Such an error can be substantial if the aerosol component is small.

3.5.4 Ozone Lidar Experiment

A 1975-76 experiment was conducted at MLO to measure the vertical ozone profile. A report of the experiment results and an error analysis is in preparation (Fegley and Penny, 1978). It appears possible to use a UV lidar system to measure the ozone profile up to 25 km with an absolute accuracy of 10%.

3.6 Surface Aerosol Measurements

3.6.1 Introduction

The 1977 GMCC surface aerosol program included the measurement of Aitken nuclei at all sites and integrated light scattering (using four wavelength nephelometers) at Barrow, Mauna Loa, and Samoa.

The routine Aitken nuclei monitoring instrument at each site is a General Electric condensation nuclei counter, modified to increase sensitivity and improve stability. For a detailed description of this instrument, see the 1976 GMCC Summary Report.

A long-tube Gardner counter is located at each site to provide routine Aitken nuclei measurements and calibration checks for the G.E. counter. This instrument is sensitive to aerosol concentrations below 100 nuclei cm^{-3} and is useful at field sites because of its portability.

A Pollak condensation nuclei counter is located at each site as a secondary standard for on-site calibration of the routine monitoring instruments using natural aerosol. The GMCC program uses the model 1957 Pollak counter with convergent light beam, manufactured by BGI Inc., Waltham, Mass. The calibration table was given in the 1973 GMCC Summary Report.

Absolute calibration for the Aitken nuclei program is provided by a photographic Aitken nuclei counter, constructed by A. Hogan of Atmospheric Sciences Research Center at SUNYA, that can be transported to sites for comparison with on-site standards. A monodisperse aerosol generator is used as a standard for laboratory instrument calibration.

Four-wavelength nephelometers at the observatory sites provide continuous light scattering measurements of the surface aerosol. The Mauna Loa nephelometer was described in the 1974 GMCC Summary Report, and the more sophisticated version at the other stations was described in the 1976 Summary Report.

The nephelometers are calibrated by filling them with CO_2 gas at 2-mo intervals and adjusting the instrument's output to read the known scattering coefficients of CO_2. An internal calibration check is performed weekly.

Instruments used in the field during 1977 are summarized as follows:

Instr.	Barrow	Mauna Loa	Samoa	South Pole
Standard Gardner Counter	x	x	x	
Longtube Gardner Counter	x	x	x	x
G.E. Counter	x	x	x	x
Pollak Counter	x	x	x	x
4λ Nephelometer	x	x	x	

3.6.2 Barrow

Longtube Gardner counter SN 1176 and Pollak counter SN 16 were operated at Barrow throughout 1977. The Gardner counter was operated occasionally for a self-calibration check, and the Pollak counter was operated daily during clean conditions to provide a calibration check on the G.E. counter. The Pollak counter operated properly all year.

The G.E. nuclei counter was operational all year, and data were stored on magnetic tape. Calibrations were performed weekly, and a routine daily check provided quality control. The counter was calibrated only during background conditions.

A new four-wavelength nephelometer (SN 105) was installed in February 1977. Data for the year were recorded on magnetic tape. Light scattering at Barrow was ordinarily in the range of 10^{-6} m^{-1} to 10^{-5} m^{-1}; occasionally during locally polluted conditions it was as high as 10^{-4} m^{-1}.

3.6.3 Mauna Loa

Longtube Gardner counter SN 1185 and Pollak counter SN 13 were operated hourly during the normal working day throughout 1977. All data have been keypunched and stored on magnetic tape.

The G.E. condensation nuclei counter operated properly throughout 1977, and all data were recorded on a chart recorder and stored on magnetic tape. The hourly Pollak counter observations provide calibration points for the G.E. counter, and all data are scaled accordingly.

The Mauna Loa nephelometer operated properly from January 4 to September 30, 1977. In October, data deteriorated, and the instrument was shipped to the University of Washington, Seattle, for repair. The problem was diagnosed as a faulty photomultiplier. The nephelometer was given a general tuneup and was found to be in excellent condition after nearly 4 yr of continuous operation. The instrument's linearity was

checked and adjusted, primarily in the digital-to-analog converter section. Noise filters were added to the clean-air valve assembly, and a photon-counting preamplifier was added at the output of the photomultiplier to reduce the current delivered by the photomultiplier. All 74193 and 7416 integrated circuits were replaced by 74C193 and 74LS05 chips to reduce the load on the 5-V power supply. Finally, some changes, which are noted in the manual with the instrument, were made in the 2^6 offset null circuitry to facilitate adjustment. The nephelometer was put back into operation at Mauna Loa on January 30, 1978. All 1977 data were recorded on a chart recorder and magnetic tape.

A new clean-air valve assembly was installed on the Mauna Loa nephelometer on July 15, 1977. This valve assembly is the same as those used on the other GMCC nephelometers.

3.6.4 Samoa

Longtube Gardner counter SN 912 was operated regularly during uncontaminated conditions throughout 1977. Pollak counter SN 20, installed in the Samoa clean-air facility on July 21, 1977, operated properly throughout the rest of the year.

A modified G.E. nuclei counter, installed in the Samoa clean-air facility on July 21, 1977, operated properly throughout the rest of 1977. This instrument was setup and calibrated initially using the Pollak counter, and data were recorded on a chart recorder and magnetic tape. Output to ICDAS was scaled at 1 V decade $^{-1}$ according to the relationship voltage = log (nuclei 3^{-1}). A calibration check and background adjustment were performed daily, and a full calibration was performed weekly.

Four-wavelength nephelometer SN 106 was installed in the clean-air facility on July 21, 1977. Initially, the instrument did not operate properly, and the problem was traced to a spiderweb inside the sample volume that was providing a bright signal which overloaded the photomultiplier. After the interior was cleaned, the instrument was checked, calibrated, and put into operation. Data were recorded continuously on a chart recorder and magnetic tape, and the instrument operated properly throughout the rest of the year. Internal calibration checks were performed weekly, and a single CO_2 calibration was performed on October 31, 1977.

3.6.5 South Pole

Longtube Gardner counter SN 1183 was operated occasionally for a self-calibration check but not routinely as a monitoring instrument. Pollak counter SN 15 was operated twice daily during clean conditions and had no problems during the year. The modified G.E. nuclei counter operated properly for the entire year, and data were recorded on magnetic tape. Daily comparisons were made between the Pollak and G.E. nuclei counters and agreement was generally good.

3.6.6 Data Analysis

Aerosol data are routinely analyzed according to the flow diagram in Fig. 20. At each site the ICDAS system produces a magnetic tape containing raw data for each 10-day period. These 10-day tapes are mailed to the Boulder reduction facility where working tapes are created monthly.

Analysis of aerosol data is accomplished by comparing chart recorder data, observer daily check forms, and computer printouts every 10 days. This routine provides the fast turn-around necessary for instrument maintenance and quality control. When a monthly tape becomes available, aerosol data are read onto a disc file in the NOAA CDC 6600 computer for calibration and editing. At this time, missing data are filled in from the chart records, data quality is evaluated (e.g., erroneous measurements due to instrument malfunctions, etc., are deleted from the record), and a final disc file is constructed of all accepted data. At the end of a year, the finalized data files are assembled into an archive tape and sent to Asheville, N.C. The following archived data are available:

Barrow	Pollak - 1975, 1976*
Mauna Loa	Nephelometer - 1974, 1975, 1976**
	Pollak - 1974, 1975, 1976*
South Pole	Pollak - 1974, 1975, 1976*

*Tape GPOL01
**Tape MLONF1

3.6.7 Discussion of Selected Data

Monthly means of condensation nuclei concentrations derived from Pollak counter data taken during clean-air conditions at all four observa-

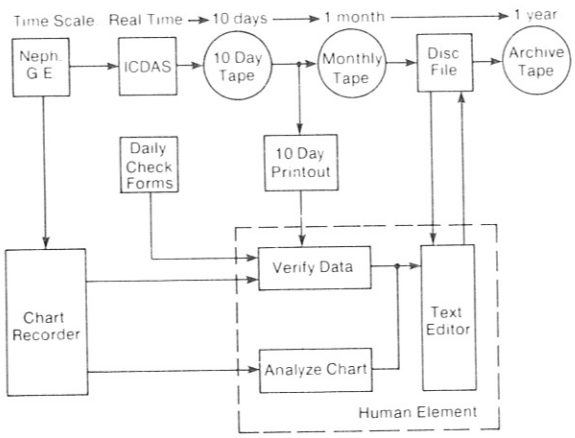


Figure 20. Flow chart for aerosol data analysis.

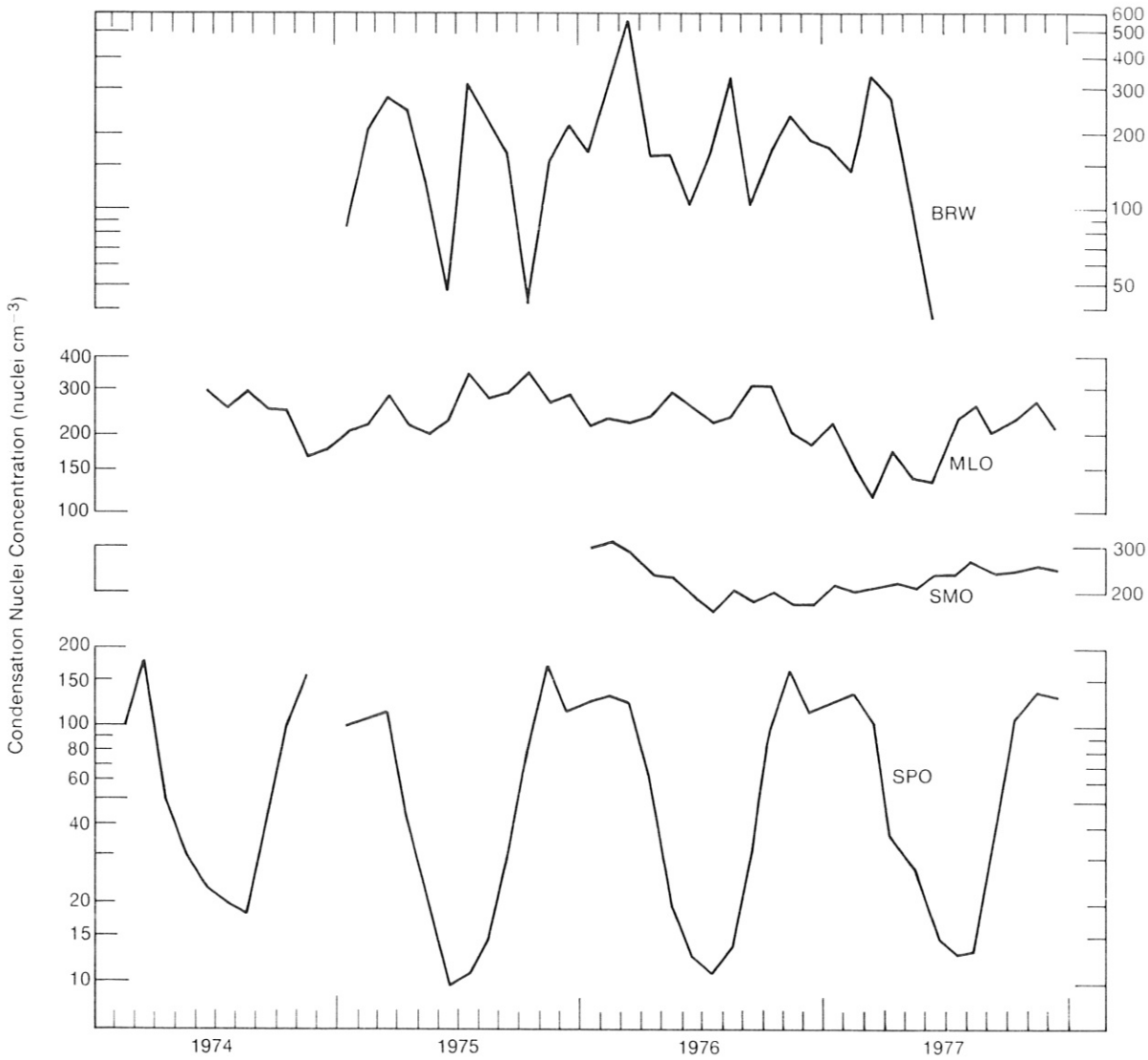


Figure 21. Monthly geometric mean concentrations of condensation nuclei at Barrow, Mauna Loa, Samoa, and South Pole for 1974-1977.

atories since the beginning of the GMCC aerosol program are given in Fig. 21.

Nuclei concentrations vary greatly at Barrow even under clean conditions; they are highest during March, July, and August, and lowest during June, September, and October of each year. Although several natural and antropogenic aerosol sources have been identified for the Barrow site, it is often difficult to identify the specific source. One possible source is the arctic haze that occurs in early spring; another

is the increase in human activity upwind from the station during this period because of sun-up and warmer temperatures. Human activity east of the station decreases markedly in June because of the melting of ocean ice and then increases sharply in July and August when the coastal waters are open for barge traffic. However, many documented cases of large aerosol concentrations (~3000 cm^{-3}) have occurred during apparently uncontaminated periods with winds from the clean air sector and clear sunny conditions in March and in July. These cases are apparently associated with clear, sunny conditions following fog or with unusual upper level wind flow. Routine Pollak counter observations were terminated in Barrow in July 1977 because of the excellent performance of the G.E. counter.

Mauna Loa nuclei concentrations in Fig. 21 are monthly means of the 1000-h observation, considered to be most representative of background conditions. An annual variation is evident with concentrations of about 180 cm^{-3} in winter and about 300 cm^{-3} in summer, but no long-term trend is apparent.

The monthly means of nuclei concentration for Samoa in Fig. 21 were calculated from Gardner counter data before July 1977 and Pollak counter data after that time. The Gardner counter and Pollak counter were compared during August 1977, and a correction factor of 1.65 was applied to all previous data acquired with Gardner counter SN 912. These corrected data, shown in Fig. 21, give nuclei concentrations between 200 cm^{-3} and 300 cm^{-3} with no apparent annual or long-term trend.

In July 1977 a photographic condensation nuclei counter was transported to Samoa and compared with Pollak counter SN 20 on ambient Samoa aerosol. This comparison consisted of 34 simultaneous measurements, and the results are shown in Fig. 22. Nuclei concentrations remained fairly

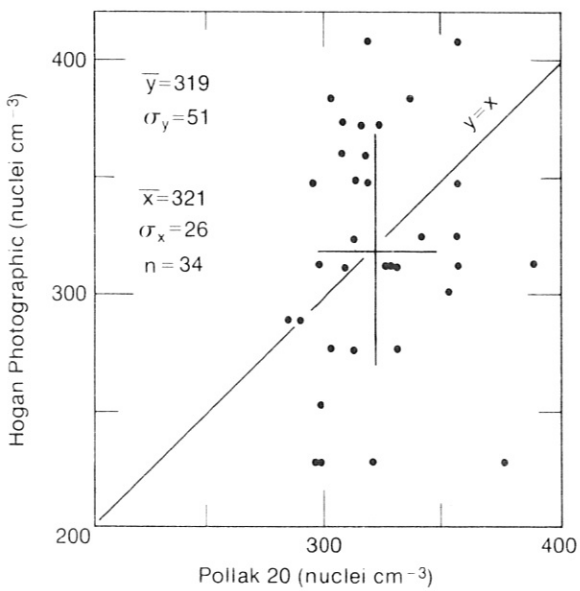


Figure 22. Comparison between ambient aerosol concentrations measured by a photographic nuclei counter and Pollak counter SN 20 on ambient aerosol at Samoa on July 20, 1977.

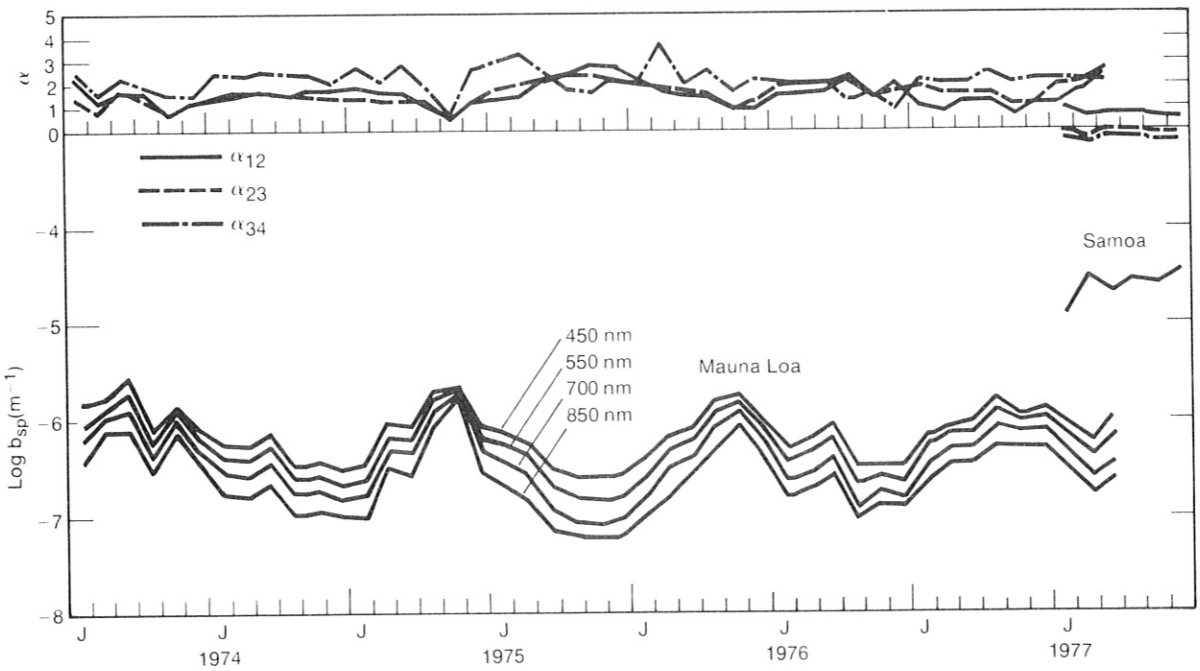


Figure 23. Monthly geometric means of Angstrom exponent and light scattering at Samoa and Mauna Loa. All data were used to calculate means for Samoa whereas only nighttime data were used for Mauna Loa. Four channels of light scattering data are shown for both Samoa and Mauna Loa.

constant (as deduced from the G.E. nuclei counter) over the comparison period so that these comparisons may be considered a one-point calibration. The center of the cross gives the mean photographic and Pollak observations, and the arms of the cross show the standard deviations. The y=x line is shown for comparison. If the two instruments were in perfect agreement, the cross would lie on the line.

A. Hogan began the Aitken nuclei monitoring program at the South Pole by installing a Pollak counter in 1974. The obvious annual cycle (see Fig. 21) has been discussed in detail by Hogan (1975). The very low midwinter values approaching 10 cm^{-3} are repeated each year as are the small peaks in November, apparently caused by the sudden breakthrough of surface winds from the coast of Antarctica. April, May, June, and July 1976 data in Fig. 21 were recovered from the G.E. counter data when a leak developed in the Pollak sample intake system.

Four-wavelength nephelometer light scattering measurements have been made at Mauna Loa since January 1974. Preliminary data were presented by Bodhaine and Mendonca (1974), and a complete report of three years of light scattering and meteorological data is available (Bodhaine,

1978). Figure 23 shows monthly geometric means of light scattering (lower) and Angstrom exponent (upper). A distinct annual variation appears in the light scattering data with a minimum of about 2×10^{-7} m^{-1} in winter and a maximum of about 2×10^{-6} m^{-1} in summer. The Angstrom exponent data indicate a tendency toward larger particles in summer and smaller particles in winter; however, no long-term trend is apparent. Angstrom exponents were calculated from the relationship:

$$\alpha_{ij} = \frac{\log b_{sp}(\lambda_i) - \log b_{sp}(\lambda_j)}{\log \lambda_i - \log \lambda_j}$$

Figure 24 shows monthly means of light scattering at MLO for each hour of the day for selected months of 1977. These data show the same general features as similar data published in previous GMCC Summary Reports.

Monthly means of light scattering data for the last half of 1977 at Samoa are also shown in Fig. 23. The values of 2 to 3×10^{-5} m^{-1} are

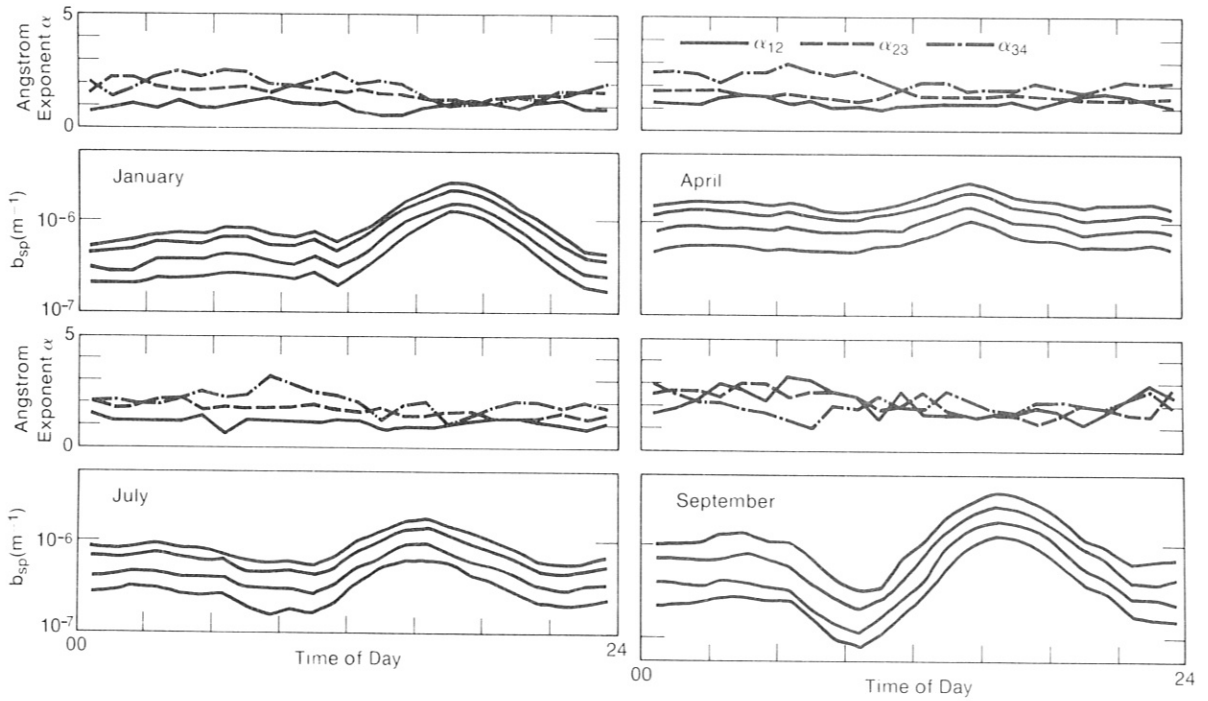


Figure 24. Monthly geometric means for each hour of the day for Mauna Loa four-wavelength nephelometer for selected months of 1977. α_{12} is derived from 450 nm and 550 nm, α_{23} from 550 nm and 700 nm, and α_{34} from 700 nm and 850 nm.

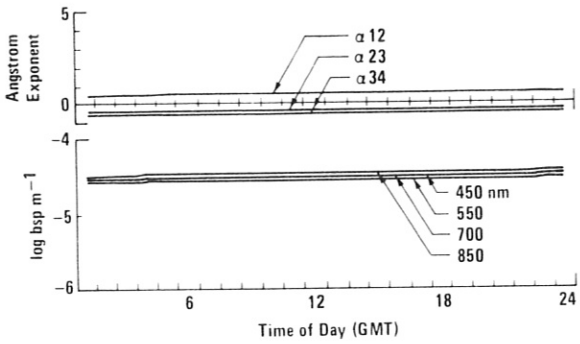


Figure 25. Monthly geometric means for each hour of the day for Samoa four-wavelength nephelometer for August 1977. α_{12} is derived from 450 nm and 550 nm, α_{23} from 550 nm and 700 nm, and α_{34} from 700 and 850 nm.

typical of marine aerosol; these are two orders of magnitude larger than the cleanest values at Mauna Loa. Monthly means of the Angstrom exponent for Samoa aerosol are shown in the upper part of the Fig. 23. Although α_{12} is about 0.5, α_{23} and α_{34} are both negative, suggesting that the Samoa marine aerosol may be composed of a narrow aerosol size distribution centered at about r = 0.9 μm (Porch et al., 1973).

Figure 25 shows the monthly mean for each hour of the day for light scattering data at Samoa. This figure is for August 1977 but is typical of the 1977 data and shows no diurnal variation. Although the magnitudes of light scattering at all four wavelengths are close to 3×10^{-5} m^{-1}, they are clearly in the order 835, 450, 700, 550 nm, causing negative Angstrom exponents for the 550-to 700-nm and 700-to 835-nm wavelength pairs.

3.7 Meteorological Measurements

3.7.1 Instruments

An absolute humidity monitor at the Amundsen-Scott station at the South Pole added the only new parameter to the weather measurements program in 1977. Through the cooperation of A. Hogan of ASRC/SUNYA, the GMCC staff interfaced a moisture monitor (DuPont model No. 303, DuPont Instruments, Wilmington, Del.) to the Instrumentation Control and Data Acquisiton System. Two operational amplifiers with a gain of about 100 were used to complete the interface without loading the instrument and to provide the necessary signal amplification. In the moisture meter, air is passed over a thin film of phosphorous pentoxide that is deposited between electrodes. The cell is constructed so that all water vapor entering the chamber is absorbed, and the voltage applied to the electrodes causes electrolysis. The current that results is proportional to the amount of water vapor. The absolute humidity, which is displayed on a meter, is recorded. The data will be archived as dew point temperature with respect to water. Recordings of the moisture data began on March 27, 1977.

The thermistors used to measure air and snow temperature at Amundsen-Scott were replaced during the year because they were nonlinear (±0.1°C) below -50°C. The replacement thermometers employ a platinum resistance element (Stolab model PL-406TT10, Stow Laboratories, Kane Industrial Park, Hudson, Md.) and companion bridge circuit (Stolab model 954PL-CO) that have ±0.1°C accuracy to -85°C. (The all-time minimum temperature reported at Admunsen-Scott was about -80°C.) The platinum resistance thermometer was mounted in a naturally-ventilated radiation shield (Young model 43103-A, R. M. Young, Traverse City, Mich.) at a height of 2.3 m. The snow temperature probe is located about 0.5 m below the snow surface. The new thermometers began operation on March 19 and July 2. The older thermistors were not discontinued until the end of the year so that a 9-mo intercomparison could be conducted. At temperatures above -50°C a preliminary analysis showed the average temperature difference between the thermometers to be +0.3°C for wind speeds greater than 3 m s^{-1}. On the average the platinum element indicated warmer temperatures than the thermistor even though the thermistor is about 1 m above it. Further analysis is needed to develop a correction equation for past years' data.

Snow and air thermometers were checked against an alcohol-in-glass thermometer in an isopropyl alcohol bath over the full range of temperatures from -80°C to 0°C. Both sensors were within ±0.5°C over this temperature range.

All weather sensors in use at the GMCC facility at the South Pole were moved during January 1977. The wind sensor was moved from the mast it shared with the station anemometer to a location approximately 160 m, grid north, and its height was changed from about 1 m to 10 m above the snow surface. The new facility is about 6 m above the previous site, resulting in a decrease in the average station pressure as measured by the GMCC sensor. The pressure sensor is about 4.8 m above the snow surface. The thermometer, which previously was mounted on a wooden pole at a 2-m height, is now attached to the anemometer mast at a 3-m height.

The instruments for wind and temperature at Cape Matatula, Samoa, were destroyed when their tower blew over in December 1976. They were reassembled and mounted on a new tower atop Lauagae Ridge. The anemometer and thermometers are about the same height above ground as before; the anemometer is now at a height of 14.5 m, and the thermometer at 9 m above local terrain. Both sensors are about 50 m higher in elevation with respect to sea level at the new location.

3.7.2 Barrow Climatology

The GMCC observatory at Barrow, Alaska, is located on tundra between two salt marshes 7 km southwest of the point. Since no significant topographic barriers are within a 300-km radius of the station, the surface wind is mainly determined by large scale synoptic weather features. Between stormy periods, when the wind is frequently from the west, the local winds are governed by the outflow from the polar anti-

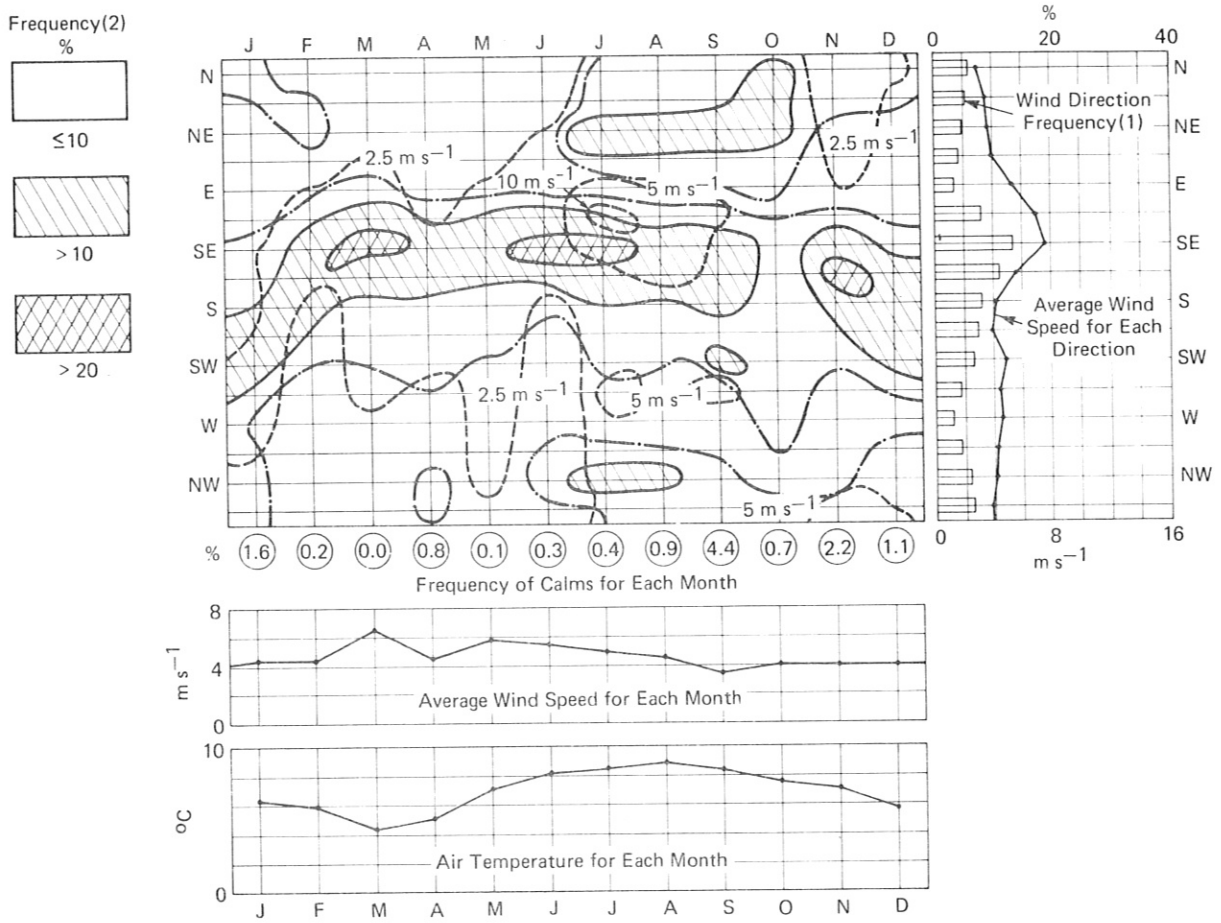


Figure 27. 1977 surface wind and air temperature data for Mauna Loa Observatory. (See legend, Fig. 26).

GMCC Summary Reports. 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 Observatory; (2) tabulations of daily tradewind temperature inversions and moisture cutoffs in relation to the height of the observatory; (3) computations of the gradient (850-mb) and jet stream (250-mb) wind layers.

Figure 29 shows the daily precipitable water during 1977 above the altitude of Mauna Loa Observatory. Highest values (maximum of 13.5 mm) occurred from August to November and March to April. On most days from December through June the atmosphere above MLO is dry with less than 20-mm precipitable water. The dry conditions are usually associated with a strong trade wind inversion capping the moist, maritime near-surface layer.

The plot of cutoff tradewind temperature inversions as determined from the Hilo soundings is shown in Fig. 30 a cutoff tradewind tempera-

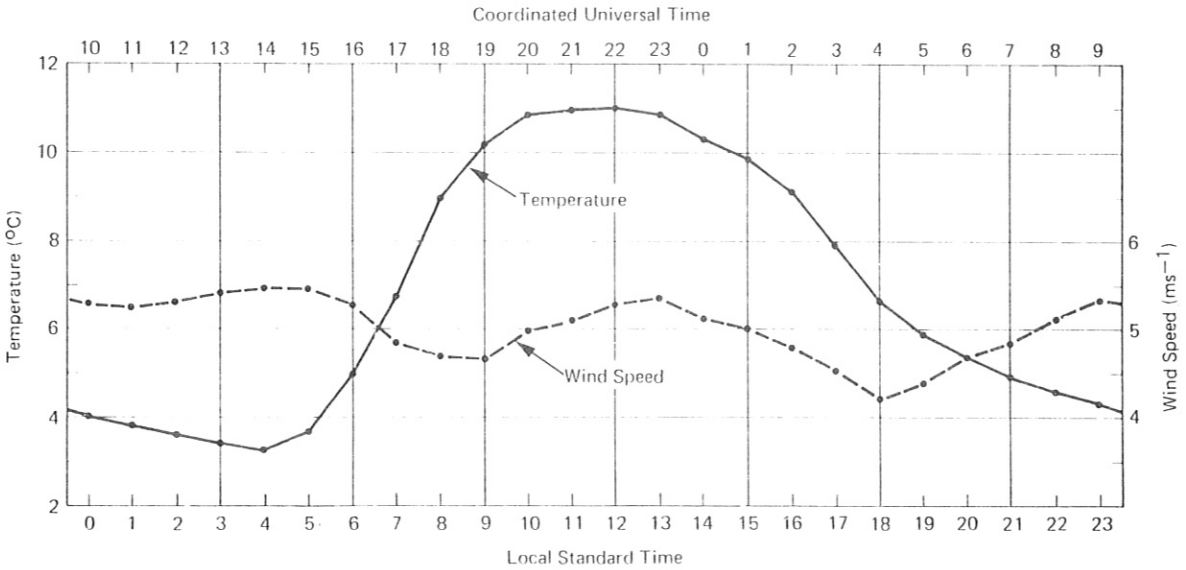


Figure 28. 1977 average temperature and wind speed vs. time of day for Mauna Loa Observatory.

ture inversion is defined as one in which the mixing ratio drops from about 6 to 10 g kg^{-1} to less than 2.0 g kg^{-1} across the inversion layer. The strength of the inversion (°C km^{-1}) is shown in the lower part of the figure; the atmospheric layer through which the inversion occurs is pictured on the top. Such inversions usually separate a moist, subinversion 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 inversions intensify during the summer half of the year and are then more effective in cutting off moisture from higher levels of the atmosphere.

Figures 31 and 32 are plots of the gradient and jet stream wind layers, respectively. The gradient wind layer (Fig. 31) is defined as that continuous atmospheric layer in which the wind direction is within ±12.5° from that at 850 mb. Wind direction and speed are then calculated as the average through this layer. The jet stream statistics (Fig. 32) are calculated similarly, except that the reference level is 250 mg. The year's record shows a significant daily variability in the height and thickness of both 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. Wind speed averages less than 10 m s^{-1} throughout the year.

The jet stream has an average vertical thickness of abou 5 km with a maximum from late winter into spring; this maximum coincides with the

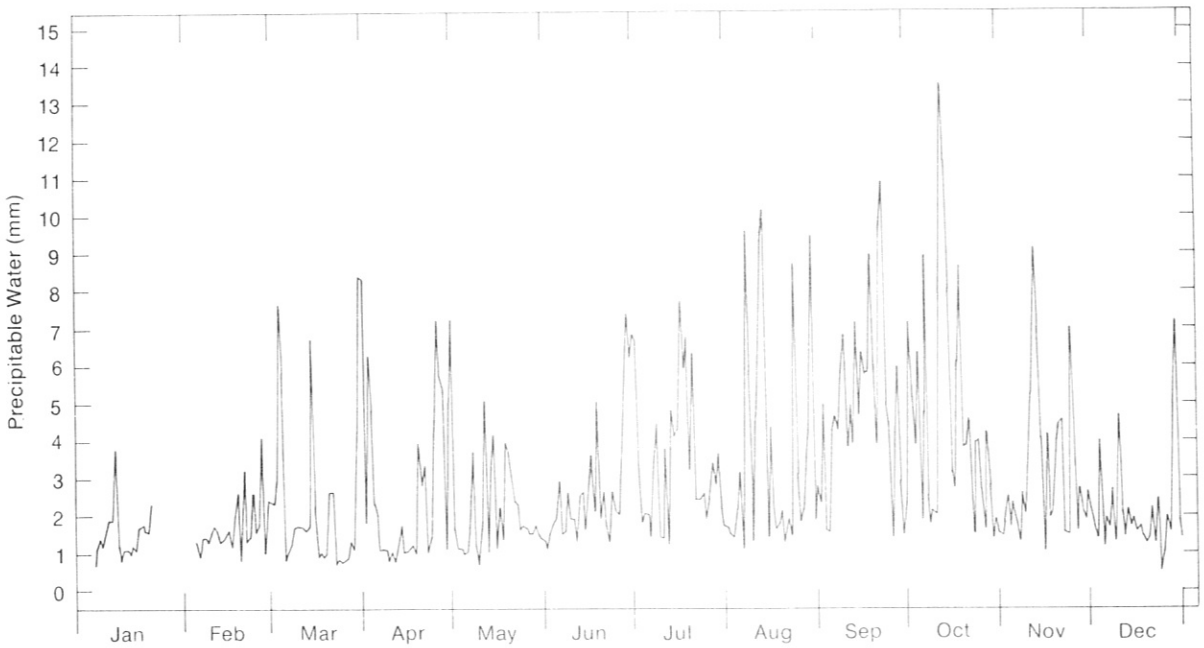


Figure 29. 1977 daily precipitable water, determined from Hilo, Hawaii, rawinsonde measurements, above altitude of Mauna Loa Observatory.

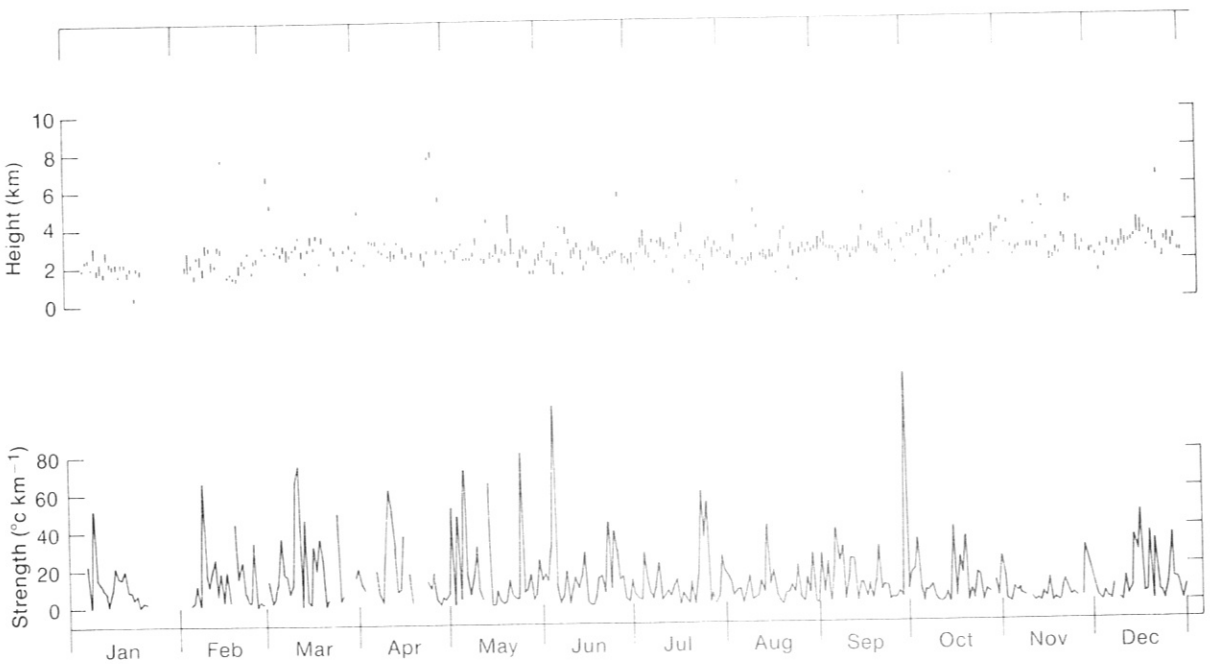


Figure 30. 1977 cutoff tradewind temperature inversions from Hilo, Hawaii, soundings. Top: atmospheric layer through which inversion occurred; bottom: strength of inversion ($^{o}C\ km^{-1}$).

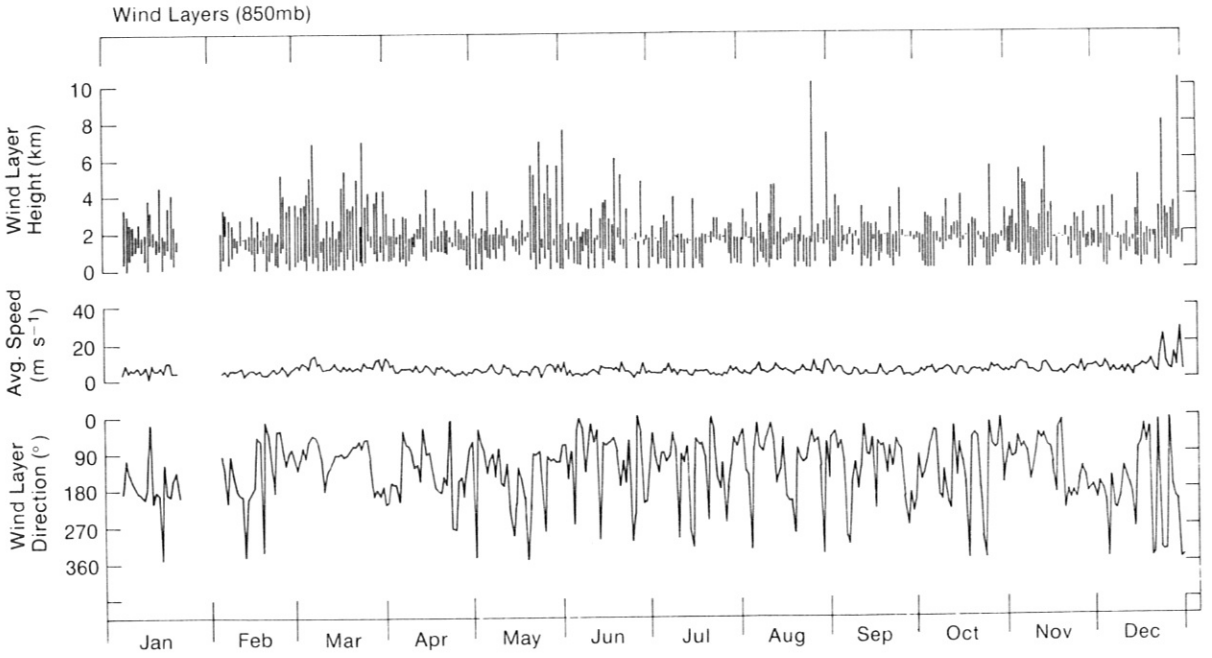


Figure 31. Gradient wind layer from Hilo, Hawaii, rawinsonde data. Vertical bars show height and thickness of layer. Wind and direction are vector sums of whole layers.

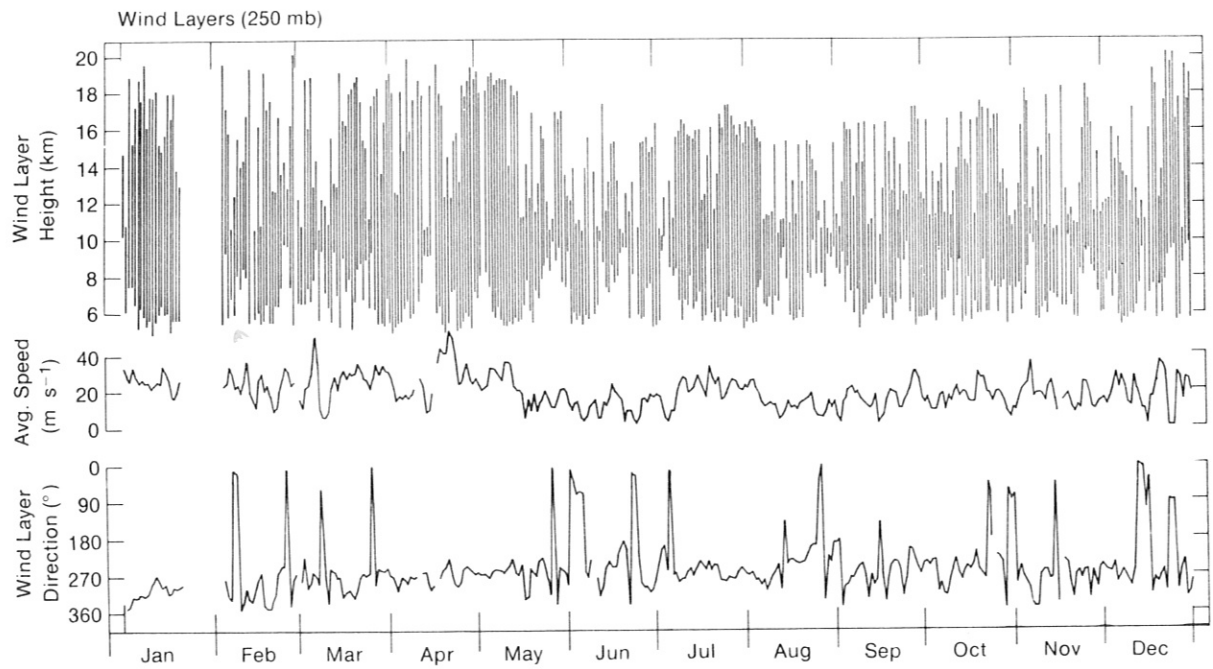


Figure 32. Jet stream wind layer plotted from Hilo, Hawaii, rawinsonde data. (See legend, Fig. 31).

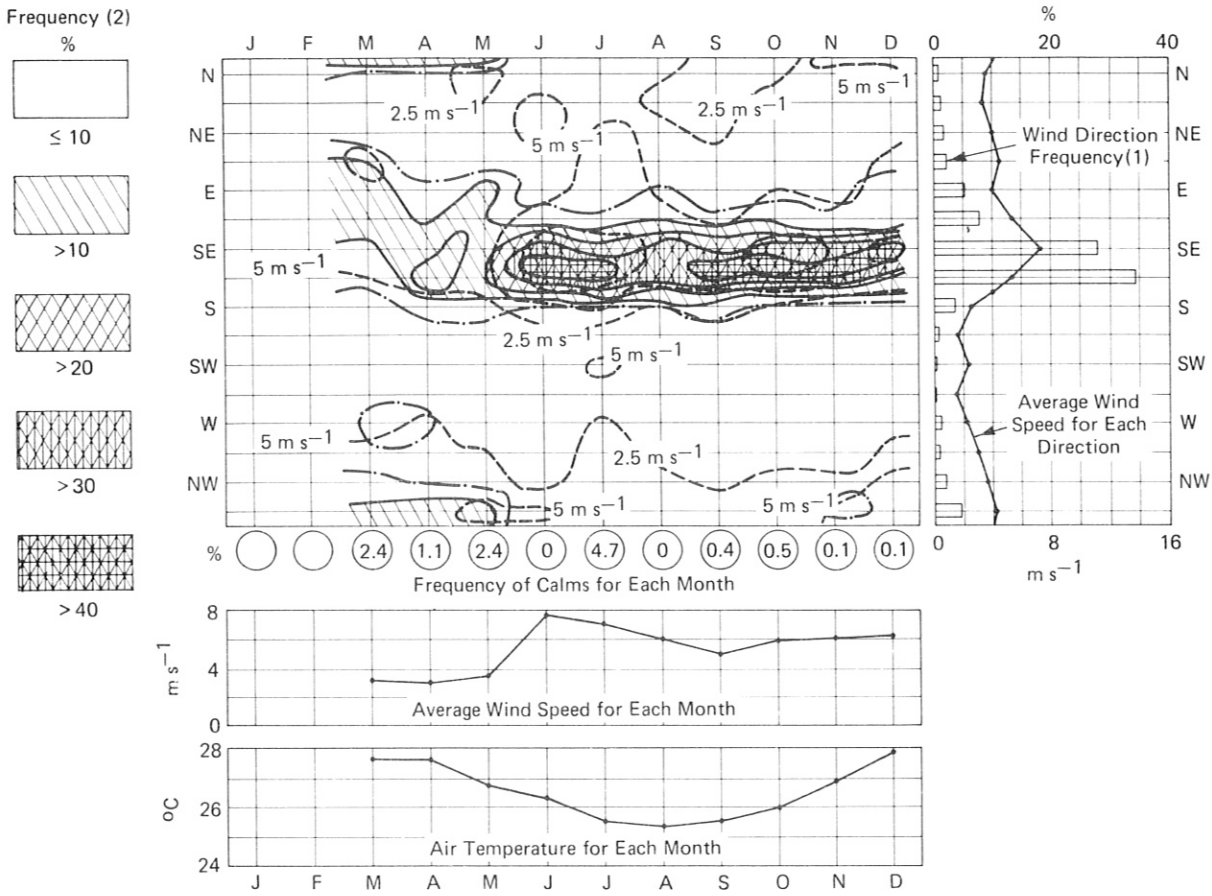


Figure 33. 1977 surface wind and air temperature data for Samoa Observatory. (See legend, Fig. 26).

annual maximum in speed. The jet stream usually flows from the west with short periods from the north or northeast.

3.7.4 Samoa Climatology

The GMCC station in American Samoa is located at an elevation of about 80 m, atop Lauagae Ridge at Cape Matatula on the Island of Tutuila. After a tropical storm destroyed the wind instrumentation on December 11, 1976, a new tower was assembled atop Lauagae Ridge, and the meteorological sensors were installed at this location. The tower was completed in February 1977; this time lapse accounts for the missing data in Fig. 33. The persistance of southeasterly trade winds at Cape Matatula is shown in Fig. 33. For one-third of the time the wind blows from the south-southeasterly direction; westerly winds occur a little more commonly than at the South Pole but still rarely. The average wind speed at Cape Matatula is 5.3 m s^{-1}. The annual average monthly percentage of calm conditions is 1.2 percent. The month-to-month change in wind speed and temperature is small.

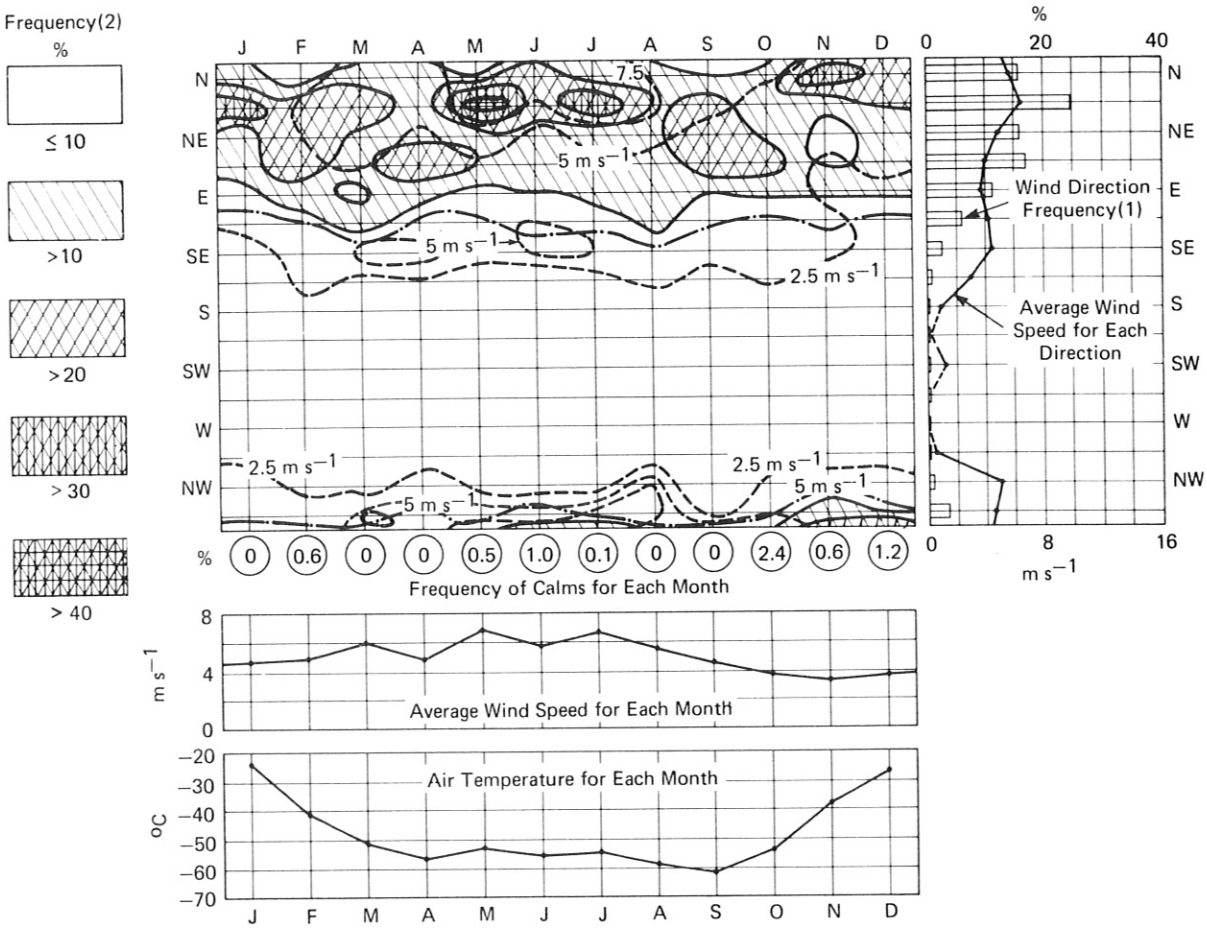


Figure 34. 1977 surface wind and air temperature data for South Pole Observatory. (See legend, Fig. 26).

3.7.5 South Pole Climatology

The persistent northeasterly winds observed in the past were again the dominant feature of the climatology at Amundsen-Scott station in 1977. These inversion winds (Schwerdtfeger, 1970), as contrasted to the stronger and more intermittent katabatic winds, blow from the antarctic dome with a deflection to the left of about 50°. The station is on the Amundson-Scott plateau at an elevation of 2.85 km. This relatively flat plateau has little relief within a 100-km radius of the station. On a larger scale the plateau is a depression near the western edge of the main high ridge of East Antarctica. The high point on the plateau (more than 4-km) is located about 900 km east-northeast of the pole.

The climatological summary for 1977 is presented in Fig. 34. The most commonly observed wind direction is from the north-northeast, with the most frequent occurrences in the Austral fall and winter months. The almost complete absence of winds from the southwest quadrant is consistent with earlier summaries. The winds are strongest during the

winter months with monthly averages of more than 7 m s^{-1}. The average resultant wind speed for the year was 5 m s^{-1}. Calm wind conditions occurred on the average only 0.5% of each month. The maximum wind speed coincided with the most commonly observed wind direction. The monthly change in temperature, like that of the Arctic, shows a rapid transition from summer to winter and an air temperature below -50°C for 8 mo per year. Only in September does the average temperature drop below -60°C. The average temperature for the year was -48.9°C.

We observed a pronounced change in the distribution of wind direction between 1977 and 1975-76. This change is most noticeable in the reduction in the percentage of time easterly components were observed. The 1977 data are more consistent with observations from the old station, close to the fuel arch (1957-1974); easterly winds were observed about 11 percent of the time in 1977 and, about 19 percent of the time at the old station. Carroll et al. (1977) suggested that the anemometers were partially shielded by the fuel arch, which could have caused this artificial increase in the occurrences of easterly winds.

3.7.6 GMCC Trajectory Program

Routine use of the GMCC air parcel trajectory program continued during 1977. Wind data, which constitute the basic input to the computer program, are derived from two sources: observed winds (available every 6 or 12 h) from the global upper air station network and analyzed winds (available every 12 h) from the National Meteorological Center in Suitland, Md., 65 x 65 Northern Hemisphere grid. Backward trajectories are computed routinely every 6 h for the GMCC observatories at Barrow and Mauna Loa, for a cooperative program at Bermuda, and to support precipitation chemistry measurements at Charlottesville, Va.,Ithaca, N.Y., White Face Mountain, N.Y., State College, Pa., and Washington, D.C. Trajectories have been computed through December 1977 for the precipitation stations and through June 1977 at the other locations.

3.8 Solar Radiation Measurements

Solar irradiance continued to be measured at all four GMCC observatories as part of the long-range monitoring of benchmark parameters. Global pyranometers and normal incidence pyreheliometers were the principal monitoring instruments. Solar irradiances were measured over broad spectral bands as well as through narrow band-pass interference filters. The broad-band measurements were made through quartz and Schott glass cutoff filters where the mean windows of measurements are quartz, 0.28 to 3.0 μm; GG22, 0.39 to 3.0 μm; OG1, 0.53 to 3.0 μm; RG2, 0.63 to 3.0 μm; and RG8, 0.695 to 3.0 μm. The filter transmittances can vary slightly with changes in ambient temperature and with different filter production melts. The ultraviolet global pyranometers in the network use a diffusing disk as well as a filter with a window between 0.295 and 0.385 μm.

3.8.1 Measurement Program

Table 15 lists the solar radiation instruments in the 1977 GMCC Solar Radiation Program by type, serial number, observatory location, filter, and calibration constant. Pyranometer measurements and tracking normal incidence pyrheliometer measurements were made and recorded continually at the four observatories.

The filter wheel NIP's completed their first measurement year at the observatories. These broad-band, normal incident measurements were made during clear sky conditions. The NIP's were manually aligned and pointed for measurement repeatability and reliability on clear days.

3.8.2 Data Acquisition

The data acquisition system for the solar radiation measurements did not change for 1977. First line data acquisition was by NOVA computers, and second line (backup) acquisition was by strip chart analog recorders. Both methods record signal voltages produced by the radiation instruments after they are amplified through a preamp bank. Preliminary processing and conversion of the millivolt signals to solar irradiance values were done by the computer at the station. Final data editing, conversions, and formating was done in Boulder before archiving. All data were adjusted for instrument and recorder system zeros and offsets. Daily documentation sheets were used to isolate external phenomena that could affect the recorded data, such as icing, snow and rain on the domes, and haze, smoke or unusual atmospheric phenomena. Instrument maintenance repairs and performances were also recorded and adjustments for them were made in data processing.

3.8.3 Instrument Calibrations and Intercomparisons

Instruments were calibrated and intercompared at the observatories and in Boulder (see Tables 16, 17, and 18). Working pyranometers and pyrheliometers were checked against designated standard instruments in

Table 15. 1977 GMCC Solar Radiation Instruments

Global Pyranometers	mV mW^{-1} cm^2	UV Pyranometers	mV mW^{-1} cm^2	Normal Incidence Pyrheliometers	mV mW^{-1} cm^2
12616-MLO-Q	0.0794	10232-MLO	1.9084	Eppley-Solar Tracking	
10151-MLO-GG22	0.0695	12348-BRW	1.869	2119-MLO-Q	0.0295
10152-MLO-OG1	0.0735	12349-SPO	2.278	11946-SMO-Q	0.0810
10153-MLO-RG8	0.0767	12350-BLD	1.869	2968-SPO-Q	0.0259
12560-MLO-Q (Diffuse Sky)	0.0970				
12263-BRW-Q	0.0956			Eppley Filter Wheel	
12265-BRW-GG22	0.0983			13909-BLD-stnd	0.0774
12264-BRW-OG1	0.1051			13911-BLD-stnd	0.0856
12267-BRW-RG8	0.0965			13910-MLO	0.0825
12273-SMO-Q	0.0927			13913-BRW	0.0826
12274-SMO-GG22	0.0963			13314-SMO	0.0829
15347-SMO-OG1	0.1048			13912-SPO	0.0815
15348-SMO-RG8	0.1047				
12271-SPO-Q	0.1072			Eppley	
12268-SPO-GG22	0.10277			11948-BLD	0.0688
12269-SPO-OG1	0.1036			11947-BLD	0.0796
12270-SPO-RG8	0.0978			11755-BLD-stnd	0.0788
				11372-BLD	0.0748
12276-BLD-Q	0.10204			3287-BLD	0.0300
12622-BLD-GG22	0.09398				
12618-BLD-OG1	0.0769			Angstrom - Standards	
12619-BLD-RG8	0.0791			12580-BLD	0.0899
12277-BLD-OG1	0.0962			10180-BLD	0.0860
12275-BLD-RG8	0.0910			12581-BLD	0.0893
12159-BLD-Q	0.0990				
10154-BLD-Q	0.0578			Kendall - Standards	
10155-BLD-Q-stnd	0.0725			12843-BLD	
12617-BLD-Q-stnd	0.0810			12842-BLD	
12502-BLD-Q	0.0952				
12562-BLD-Q	0.1003			Active Cavity Radiometer - Standards	
11538-BLD-Q	0.1041			ACR-601	
11539-BLD-Q	0.1008			ACR-602	
9876-BLD-Q	0.0618				

Table 16. 1977 GMCC Filter Wheel NIP Intercomparisons

Station	Date	Serial No. Stand. Instr.	Serial No. Test Instr.	Ratio Std./Test	Filter Factors OG1	RG2	RG8
BLD	Oct 7-8	13909	13911	1.0092	1.093	1.095	1.090
MLO	Nov 22-28	13909	13910	1.0071	1.095	1.093	1.103
SMO	Jan 6-8	13909	13914	1.0110	1.095	1.105	1.100
SPO	Dec 27-30	13911	13912	0.9802	1.094	1.098	1.122
BRW	Feb 2-4	13917	13913	0.9845	1.105	1.110	1.111

the field and in simulated field conditions in Boulder. In all comparisons the instruments were exposed to the sun under clear sky conditions and ambient temperature. Some data from cloudy sky conditions were incorporated into the intercomparisons at the field sites when not enough clear sky data could be obtained. All instrument intercomparison results were determined from daily irradiance totals.

Table 17. 1977 GMCC Pyrheliometer Intercomparisons

Station	Date	Std. Inst. Serial No.	Cal. Const. mV mW^{-1} cm^2	Test. Inst. Serial No.	Cal. Const. mV mW^{-1} cm^2	Response Std./Test	% Dif.
MLO	Feb 8-10	4758	0.0651	2119	0.0295	0.9561	+4.4
BRW	May 2-5	13909	0.0774	13913	0.0826	1.0039	-0.4
BLD	Oct 1-2	13909	0.0774	13911	0.0856	1.0105	-1.0
BLD	Sep 14-31	1330	0.0274	11946	0.0806	1.0010	-0.1
MLO	Nov 22-28	13909	0.0774	13910	0.0825	1.0071	-0.7
SPO	Dec 19-30	13911	0.0856	13912	0.0815	0.9978	+0.2
SPO	Dec 19-30	13911	0.0856	2968	0.0259	1.0706	-6.6
SMO	Jan 6-8	13909	0.0774	13914	0.0829	1.0110	-1.1

Table 18. 1977 GMCC Pyranometer Intercomparisons

Station	Date	Std. Inst. Serial No.	Cal. Const. mV mW^{-1} cm^2	Test. Inst. Serial No.	Cal. Const. mV mW^{-1} cm^2	Response Std./Test	% Dif.
MLO	1/26-31	10155 (Q)	0.0725	12616 (Q)	0.0794	1.0035	-0.35
BLD	2/17-29	12618 (OG1)	0.0769	15347 (OG1)	0.1048	0.9983	+0.17
BLD	2/17-29	12619 (RG8)	0.0791	15348 (RG8)	0.1047	0.9838	+1.62
BRW	5/2-6	10155 (Q)	0.0725	12266 (Q)	0.9919	0.9919	+0.81
SMO	5/24-6/10	15347 (OG1)	0.1048	12277 (OG1)	0.09618	1.054	-5.4
SMO	5/24-6/10	15348 (RG8)	0.1047	12275 (RG8)	0.09102	1.120	-12.0
BLD	8/22-25	12618 (OG1)	0.0769	12277 (OG1)	0.09618	1.040	-4.0
BLD	8/22-25	12619 (RG8)	0.0791	12275 (RG8)	0.09102	0.995	+0.5
BLD	4/7-21	15166 (UV)	1.87	12348 (UV)	1.87	1.105	-10.5
SPO	1/1-9	12617 (Q)	0.0810	12271 (Q)	0.1072	0.9951	+0.49

The calibration scale for the pyranometer measurements at the observatories was based on the International Pyrheliometric Scale. A multiplying factor of 1.026 is required to convert the data to the absolute radiation scale determined by WMO, and measurements based on a Kendall PACRAD radiometer, serial no. III. The pyrheliometer calibration scale is based on the 1975 International Pyrheliometric comparisons at Davos, Switzerland. GMCC instruments were calibrated with transfers from an Angstrom No. 2274 pyrheliometer, a Kendal TMI absolute pyrheliometer (No. 67504) standard of NOAA, and a silver disk No. 5178 pyrheliometer. GMCC also maintains two standard pyrheliometers (an Angstrom No. 10180 and a Kendall No. P12843) that were intercompared at Davos. The standardization of the GMCC working pyrheliometers in 1977 was made with the NOAA/ARL working NIP standard No. 1330. NIP No. 1330 produces irradiance values that are 0.975 ± 0.002 of the Kendall TMI No. 67502 irradiance values. To convert the data to the absolute radiation scale, a multiplying factor of 1.026 is required. All data (the pyranometer and pyrheliometer data) have been converted and archived in the absolute radiation scale.

3.8.4 Transition, Modification, and Development

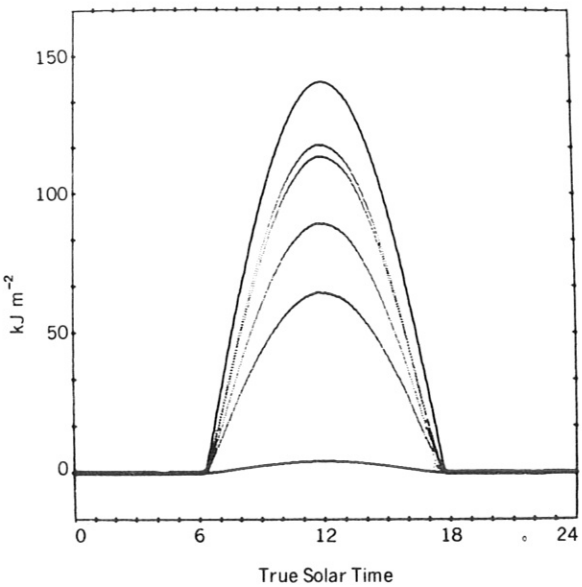
A broadband NIP filter wheel intercomparison technique was developed to maintain a history on all filter wheels in the network. From these intercomparisons, filter factors were obtained for each filter, and adjustments were made to all filter wheel data. The filter factors are listed in Table 16.

A new solar radiation platform tower was built adjacent to the main building at Mauna Loa Observatory. All solar radiation instruments were moved to this tower by August 16, 1977. The platform tower is approximately 30 ft high, and its location reduces the signal cable lengths from the instruments to the computer. A new solar radiation instrument platform was constructed on the roof of the new clean air facility building at the South Pole. The solar radiation instruments were installed on this platform on January 1, 1977.

Air blowers and de-icers were installed on the pyranometers at the South Pole and Barrow. The domes of the pyranometers were ventilated with air to remove and keep off any snow, rain, dew, or ice.

A gradual deterioration of the OG1 and RG8 pyranometer domes at Samoa was observed. Discoloration of the glass was severe enough to affect the observations by 5% of more (see pyranometer intercomparisons, Table 18). On July 1 pyranometers 12277 (OG1) and 12275 (RG8) were replaced by pyranometers 15347 (OG1) and 15348 (RG8).

Operation of the 13-channel pyrheliometers at Mauna Loa and the South Pole was temporarily suspended after repeated operational problems with the instruments. The measurements may be resumed after the instrument problems are solved.



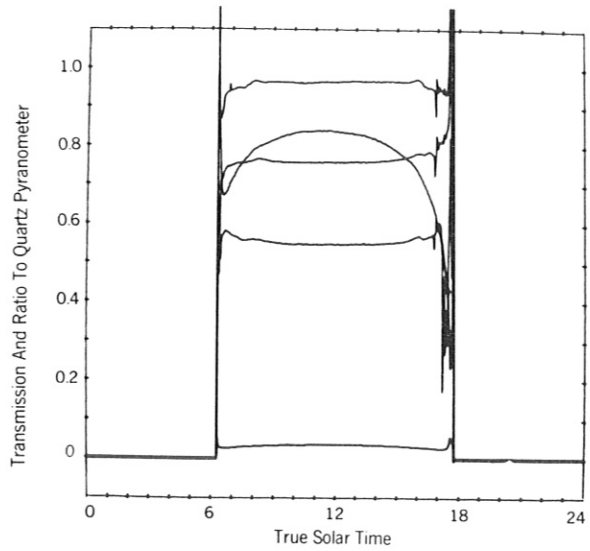


Figure 35a (left). Solar irradiance (kJ m^{-2}) at Mauna Loa Observatory on day 298, 1977. Data are extraterrestrial irradiances on a flat surface (EIR) and pyranometer meaurements with quartz (Q), GG22, OG1, RG8, and UV filters. Data are characteristic of a clear, autumn day. 35b (right). Transmittance (quartz/extraterrestrial) and pyranometer filter ratios corresponding to measurements in Fig. 35a.

The solar radiation dome was put into operation on the roof of PSRB-3 at Boulder. Preliminary testing of infrared hygrometers was begun in this dome.

Periodic diffuse sky measurements were continued at Mauna Loa, and a suitable shading ring was tested there.

3.8.5 Data Analysis

Daily plots of 2-min integrals of solar irradiances from pyranometer measurements are shown in Figs. 35 to 42. Typical plots for varying conditions are shown for the four observatories. An extraterrestrial irradiance curve (ETR), shown on each plot, is obtained by computing the horizontal incidence radiation at the top of the atmosphere using the solar constant and zenith angle of the sun. For each plot of daily solar irradiances a corresponding plot of irradiance ratio was calculated for data quality control checks (see example in Fig. 35b, for MLO data in Fig. 35a). The ratios are for quartz/extraterrestrial (transmittance, concave downwards curve), and from top to bottom, GG22/quartz, OG1/quartz, RG8/quartz and UV/quartz. Microfilm plots for every day of data are stored at the GMCC Boulder office. These data are archived in tabular form in the National Climate Center in Asheville, N.C.

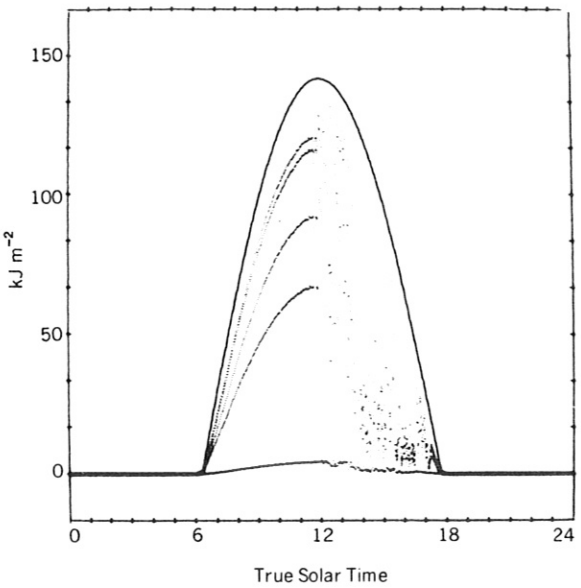


Figure 36. Solar irradiance (kJ m^{-2}) at Mauna Loa Observatory on day 295, 1977 (see legend, Fig. 35a). Data are characteristic of a typical day with clear morning and cloudy afternoon. Orographic convection and cumulus development usually occur only in the afternoon.

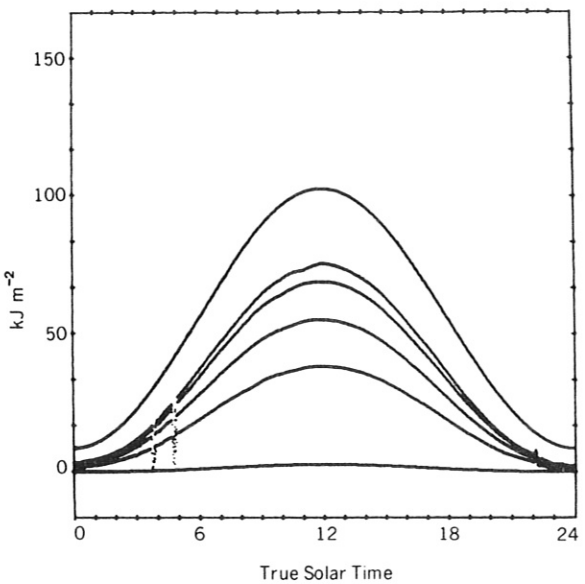


Figure 37. Solar iradiance (kJ m^{-2}) at Barrow Observatory on day 195, 1977 (see legend, Fig. 35a). Signature of two towers is seen in early morning.

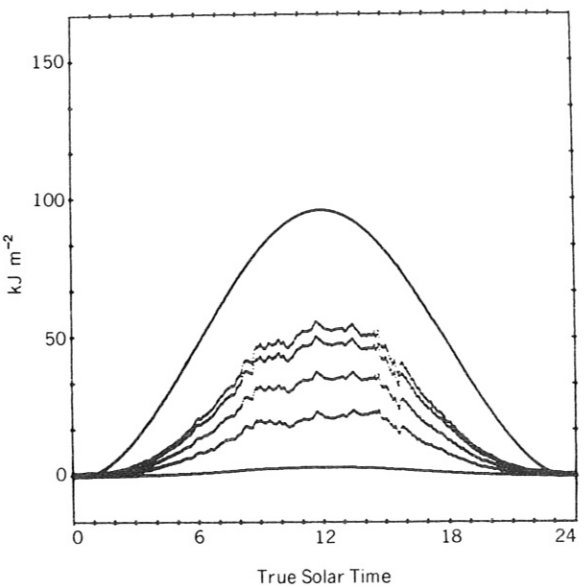


Figure 38. Solar irradiance (kJ m^{-2}) at Barrow Observatory on day 133, 1977 (see legend, Fig. 35a).

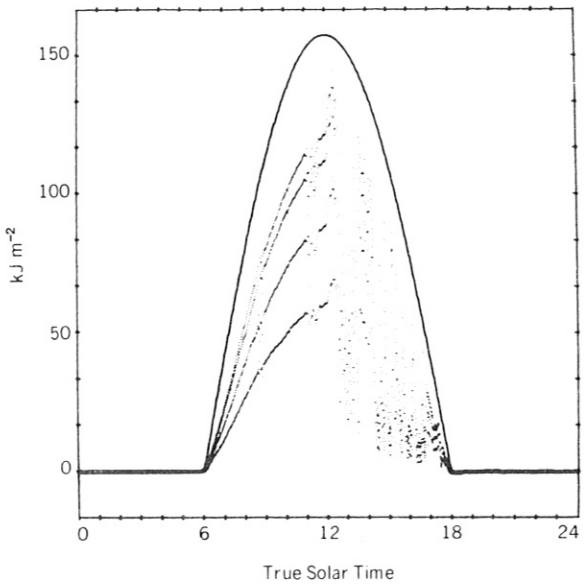


Figure 39. Solar irradiance (kJ m^{-2}) at Samoa Observatory on day 265, 1977 (see legend, Fig 35a). Data are for relatively clear morning and cloudy afternoon.

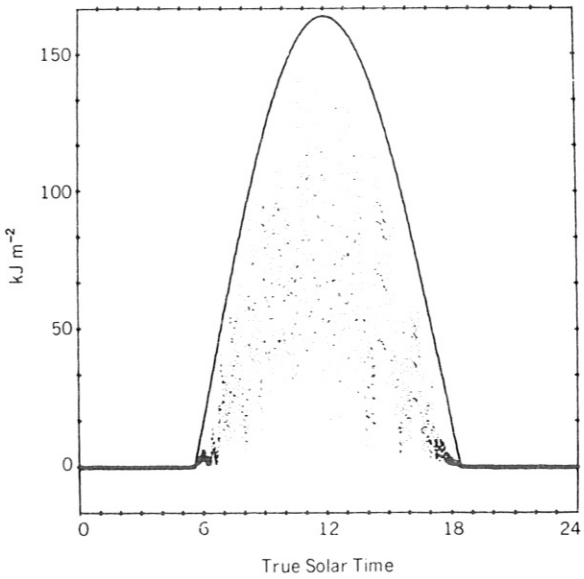


Figure 40. Solar irradiance (kJ m^{-2}) at Samoa Observatory on day 348, 1977 (see legend, Fig. 35a). Data are for typical tropical cumulus sky; intermittent cumulus build-ups and blue-sky patches cause caotic irradiance pattern.

Plots of normal incidence solar irradiances measured with filter wheel pyrheliometers at Samoa and South Pole during clear sky conditions are shown in Figs. 43 and 44, respectively. All 1977 measurements with quartz (clear) and RG8 (0.695-μm wavelength cutoff) are presented as a function of absolute air mass. Although the data show some scatter, a non-linear dependence on air mass is evident. The wide scatter at the South Pole at low solar elevations may result from very thin cirrus. Figure 45 shows the yearly average of computed atmospheric transmissions obtained from the NIP filter wheel normal incidence measurements for each filter at various air mass values. The South Pole Observatory shows the most transparent atmosphere, with MLO having one almost as clear. The two sea-level observatories show a less transparent atmosphere with Samoa's slightly less transparent than Barrow's. The high moisture content of the tropical marine atmophere at Samoa contributes to the lower transparency measured there.

In Fig. 46 the average monthly clear sky normal incidence irradiances at Mauna Loa are plotted against air mass. The data have been adjusted for a mean sun-earth distance, and filter factors have been applied to the colored filter broad-band measurements. The irradiance

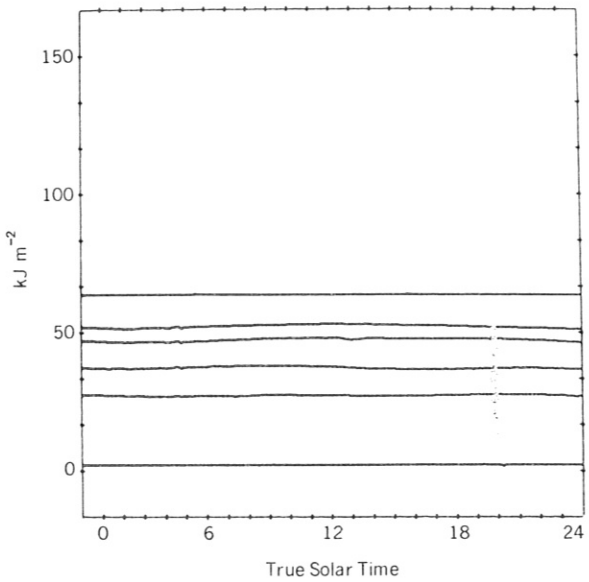


Figure 41. Solar irradiance (kJ m^{-2}) at South Pole Observatory on day 9, 1977 (see legend, Fig. 35a). Data are for clear sky period; signature of tower is seen at 1945 hours.

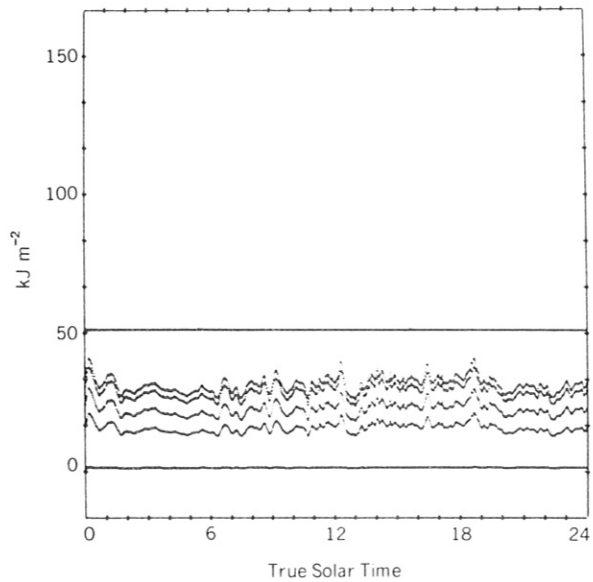


Figure 42. Solar irradiance (kJ m^{-2}) at South Pole Observatory on day 317, 1977 (see legend, Fig. 35a). Data are for overcast sky.

measured at Mauna Loa not only shows a variation with air mass as expected but an annual trend with lower values in autumn than spring for equal air masses.

A plot of the average monthly normal incidence solar irradiance transmission at Mauna Loa calculated by the method of Ellis and Pueschel (1971) is shown in Fig. 47. Monthly average values are smoothed with 6-mo running mean. Volcanoes that ejected material up to the tropopause are identified on the bottom of the figure. The lengths of the arrows correspond to a minimum estimate of altitude of the emissions determined from visual sightings and/or aircraft measurements. The transmission trends over the 20-yr record are shown. An annual variation is observed every year. Superimposed on the annual variation are longer-term trends with greater amplitudes, the biggest occurring in spring of 1963 with the eruption of Mount Agung volcano in Indonesia. Subsequent explosive volcanic eruptions also affect the transmission trend measured at Mauna Loa. The atmospheric clarity does not reach the levels measured at the beginning of the data record (pre-Agung) until the winter of 1977.

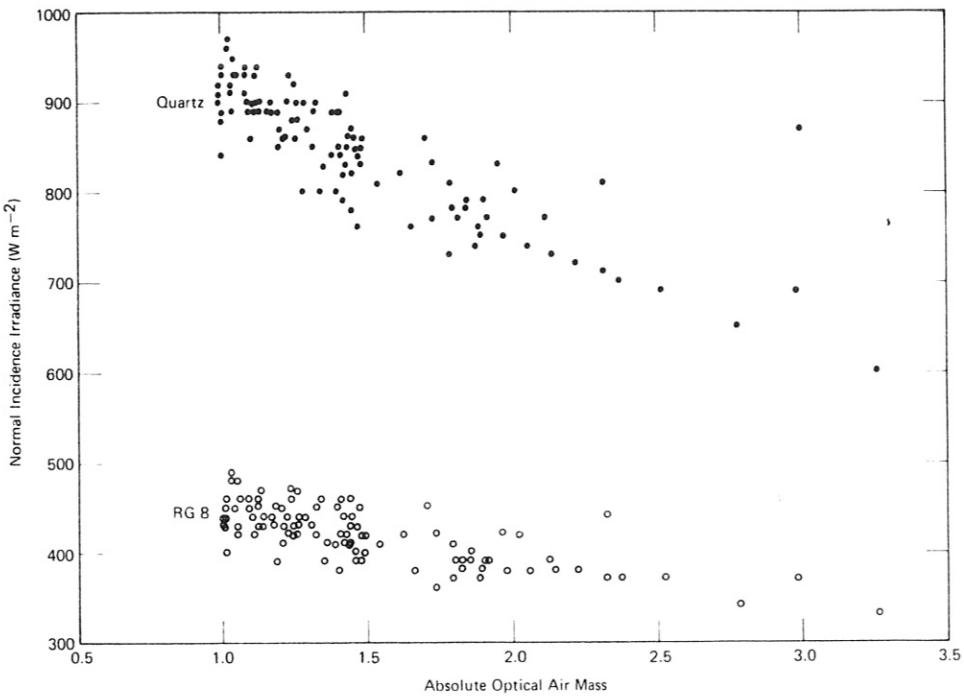


Figure 43. Normal incidence irradiance vs. air mass at Samoa. Values for quartz and RG8 filters are given for all cloudless periods during 1977.

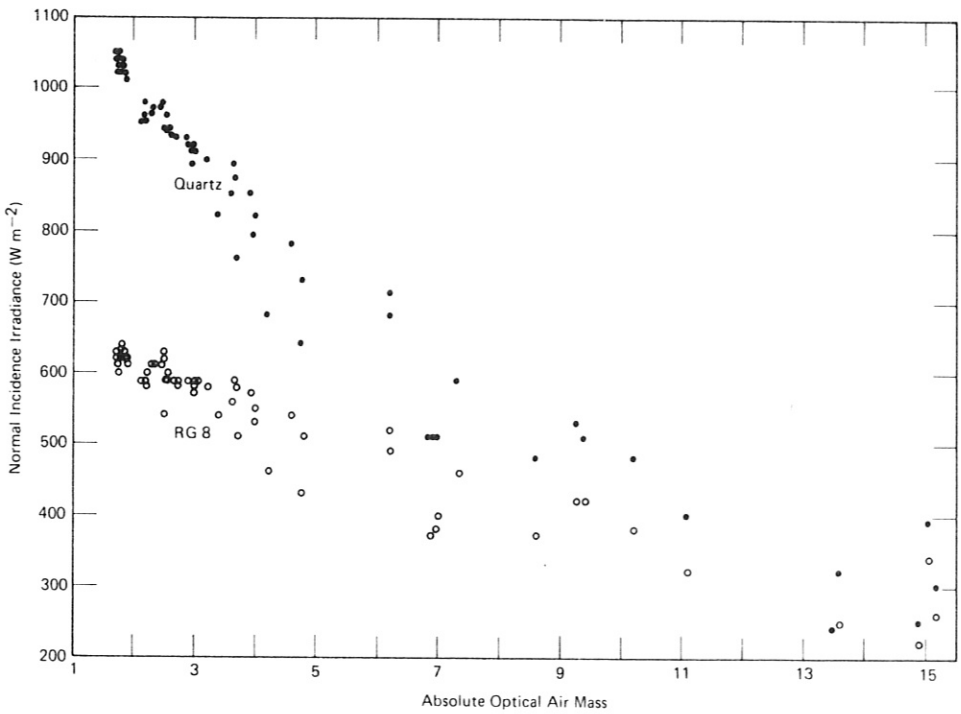


Figure 44. Normal incidence irradiance vs. air mass at South Pole (see legend, Fig. 43).

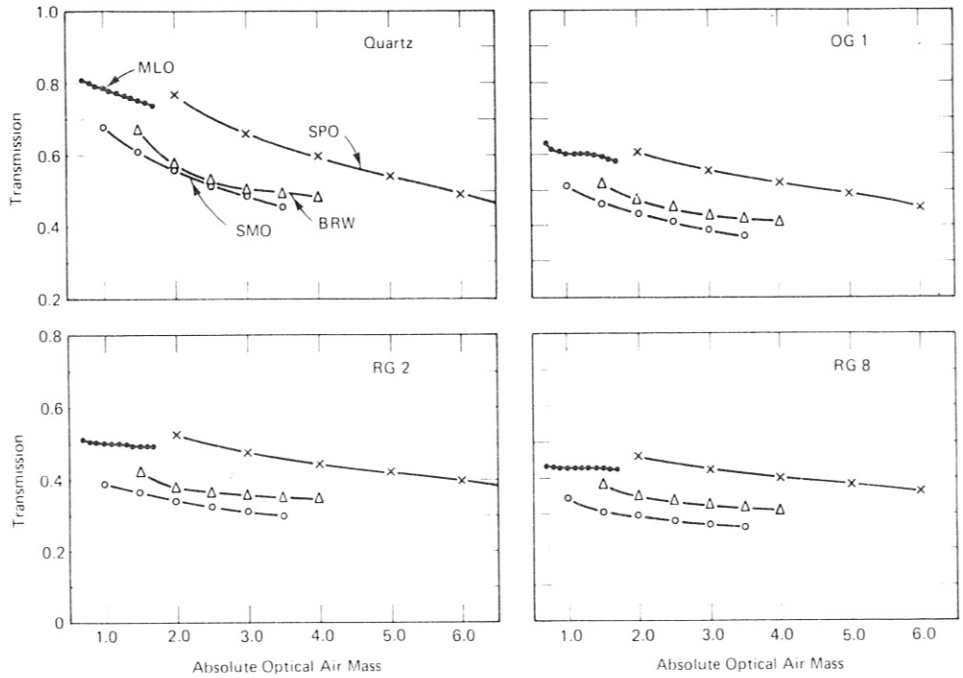


Figure 45. 1977 average normal incidence solar clear-sky transmissions for 4 observatories vs. optical air mass corrected for station pressure. Transmissions are determined by dividing irradiances from each broad-band measurement by the solar constant component on a horizontal surface (I_o).

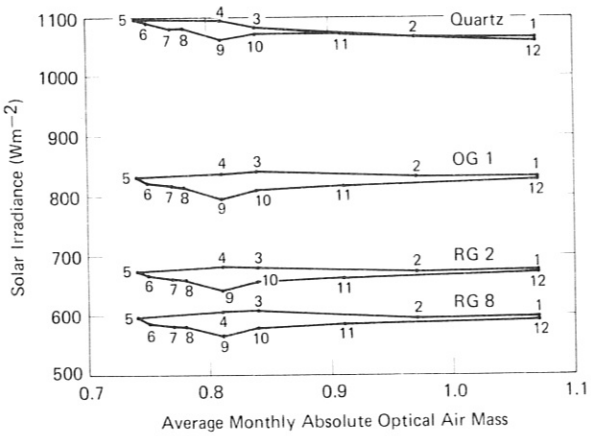


Figure 46. 1977 average monthly clear-sky normal incidence irradiances at Mauna Loa vs. air mass. Numbers refer to month.

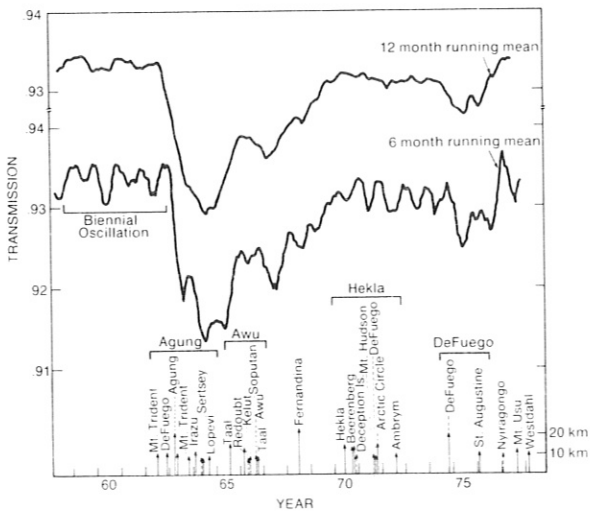


Figure 47. Normal incident solar transmissions for Mauna Loa (1958-1977).

3.9 Precipitation Chemistry Measurements

A national precipitation chemistry network under the U.S. Department of Agriculture was established in 1977. By early 1978 weekly precipitation collections for chemical analysis started at agricultural experimental stations. Cooperation between the agricultural network and the GMCC stations will continue.

Also in 1977 the precipitation chemistry work being done in federal agencies was reviewed and a report cataloging federal activity in this area was prepared (U.S. Geological Survey, 1978).

3.9.1 Baseline Operation

Mauna Loa Observatory

The program of precipitation chemistry measurements on the Island of Hawaii continued to expand (see Tables 19 and 20). All samples collected in the GMCC program were analyzed for pH and conductivity. Some samples were selected for titration and chemical analysis using the ion chromatograph (IC). Ions found on the IC included sulfate, nitrate, nitrite, fluoride, chloride, and other anions.

American Samoa

Samples were collected regularly at Cape Matatula and Tafuna. GMCC and cooperative programs at Samoa are listed in Tables 19 and 20.

Table 19. Precipitation Chemistry Programs at GMCC Observatories

GMCC Program	Place	Collection Method		Analysis
Mauna Loa	Kapoho	Bulk	3 day	pH & conductivity of all samples; some analysis for SO_4, NO_2, Cl, Br, F, NH_4, and others.
	Hilo/Halai	Bulk	Event	
	Mountain View	Bulk	Event	
	22-23 Mile	Bulk	3 day	
	Kulani Mauka	Bulk	3 day	
	MLO	Bulk	3 day	
	Kapoho	Open-close	3 day	
	MLO	Open-close	3 day	
	MLO	Cloud collec.	Event	
	MLO	Snow barrel	Event	
Samoa	Cape Matatula	Bulk	Event	pH & conductivity at site; further analysis at MLO.
	Tafuna	Bulk	Event	
Barrow	Barrow Obs.	Snow barrel	Event	No on-site analysis; samples sent to MLO for analysis.
South Pole		Grab samples		Samples to MLO for analysis.

Table 20. Cooperative Precipitation Chemistry Programs at GMCC Observatories

Observatory	Coop. Program	Collection Method	Analysis Site
Mauna Loa	EPA	Monthly samples at MLO	EPA, Res. Triangle Pk., N.C.
	Dept. Energy	Wet and dry collec. at MLO; composite samples also.	Dept. Energy, N.Y.
	Univ. of Va.	2-wk collec. at many sites in July; continual shipment since July.	Univ. of Va., Charlottesville, Va.
	Int. Atomic Energy Agency	1 event/mo at Hilo	Int. Atomic Energy Agency, Vienna, Aust., for stable isotopes
	Lab. de Geol. Dyn.	2 sites/mo	Lab. de Geol. Dyn., Paris, Fr.; sulfates and isotopes
Samoa	EPA	Monthly samples	EPA, Res. Triangle Pk., N.C.
	Dept. Energy	Wet and dry collec.	Dept. Energy, N.Y.
	Cal. Tech.	Samples for lead analysis	Cal. Tech., Pasadena, Cal.

Barrow

Because of the difficulty of collecting samples in the Arctic region, a new system was used whereby observers try to collect snow in barrels on an event basis. Surface snow will also be sampled.

South Pole

No samples were collected at the South Pole in 1977. For information on laboratory and field procedures, see previous GMCC Summary Reports.

3.9.2 Data Analysis

Mauna Loa Observatory

The average acidity of precipitation remained at 4.5 pH units for the Island of Hawaii. Samples at lower sites were less acidic compared to those at higher elevations as reported in the 1976 GMCC Summary Report. For the first time some samples were analyzed using the ion chromatograph, although tests for all major ions have not yet been made.

Figures 48 and 49 show the pH and conductivity values in samples collected in a 3-day period at Kulani (2500 m) and MLO. There is good inverse agreement between increased acidity and conductivity. The points that do not show this agreement could have been influenced by washout of neutral particles, such as NaCl, which would increase the conductivity but not change the pH. No values are shown for January at MLO because of the lack of precipitation. In general, 1977 was a dry

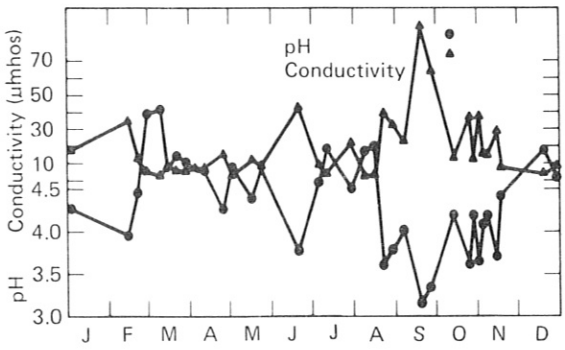


Figure 48. 1977 precipitation pH and conductivity data for Kulani, Hawaii (2,500 m).

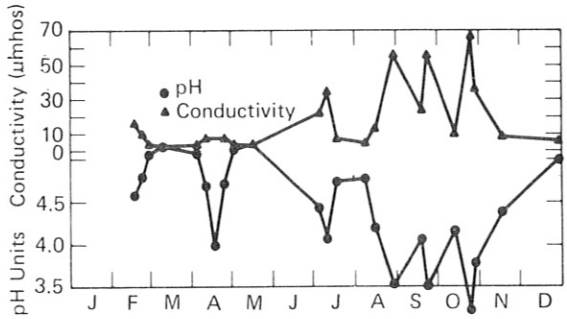


Figure 49. 1977 precipitation pH and conductivity data for Mauna Loa, Hawaii.

year compared to the past record. At MLO, only 234 mm of precipitation fell compared to the 20-yr average of 450 mm. This dryness was seen in all the island's precipitation records.

The pH values at MLO, Kulani, and Kapoho (sea level) are plotted in Fig. 50. The record indicates a slow increase in acidity (low pH) until mid-October and then a rapid decrease. One explanation of this phenomenon is that gases were emitted before the eruption on the northeast rift zone of Kilauea Volcano during late September. After the eruption the values returned to more normal levels. This increase in acidity was measured from sea level to the observatory (3400 m). The outgassing of the volcano may have affected the island's precipitation. In 1978 we plan a more thorough investigation of this possibility.

From preliminary analysis made on the ion chromatograph, the increase in the acidity was followed by an increase in the sulfate concentration in the precipitation (Fig. 51), as well as an increase in nitrates.

As seen in Fig. 52, precipitation chemistry data can be interpreted in terms of meteorological parameters. All pH data were categorized according to the average hourly wind direction when the sample was taken. In Fig. 52 the percentage of time over the 2½-yr period when the wind was from a given direction during occurrences of precipitation is given in parentheses. The pH values next to the direction are the weighted averages for that direction. Over the period the more acidic precipitation came from the northerly direction. A more detailed description of the chemistry results from the Island of Hawaii will be published in a technical report.

American Samoa

The pH values of samples collected at the two sites in Samoa are shown in Fig. 53. The acidity of the samples is less than that of those

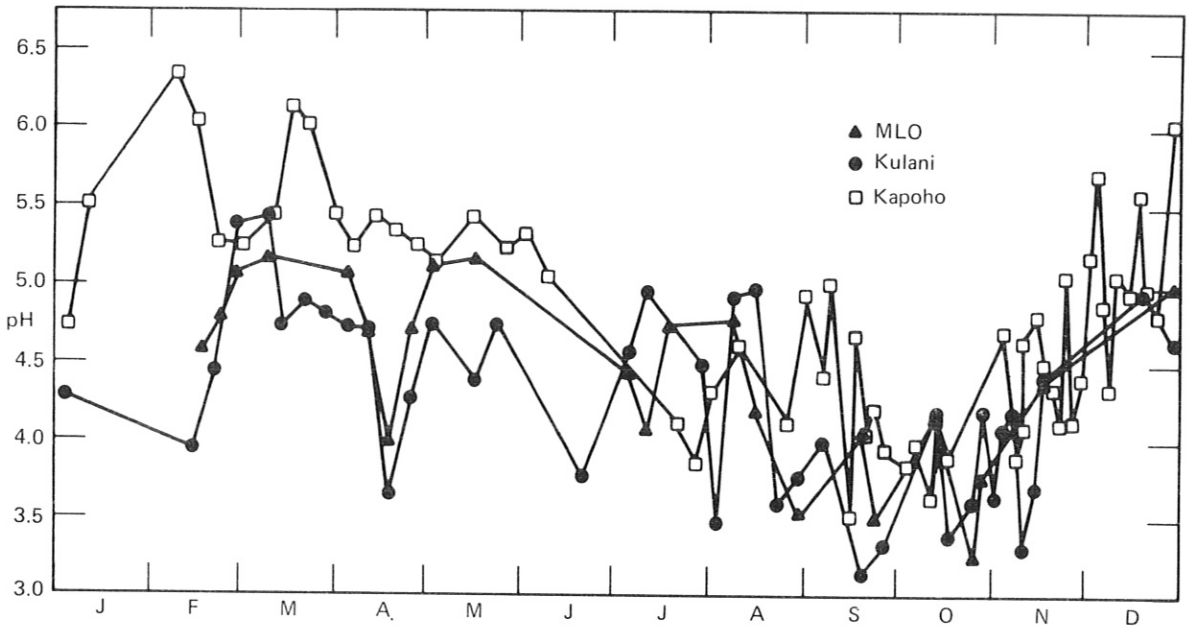


Figure 50. 1977 precipitation pH values for Kapoho (sea level), Kulani, and Mauna Loa, Hawaii.

measured in Hawaii, and monthly averages show a decrease in pH at both collecting sites in May and September.

Barrow

Samples from the snow barrel collector are being evaluated and will be presented in the next report.

3.9.3 Regional Sites

The ten WMO regional sites continued to collect precipitation each month. A survey of the qualifications of all sites as regional sites under WMO criteria is planned. The Misco collector will be replaced by an improved commercial model in 1978.

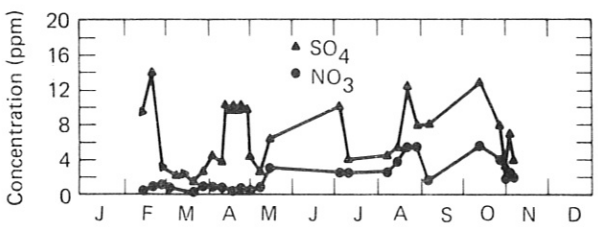


Figure 51. 1977 preliminary sulfate and nitrate values measured by ion chromatograph in samples from Kulani, Hawaii.

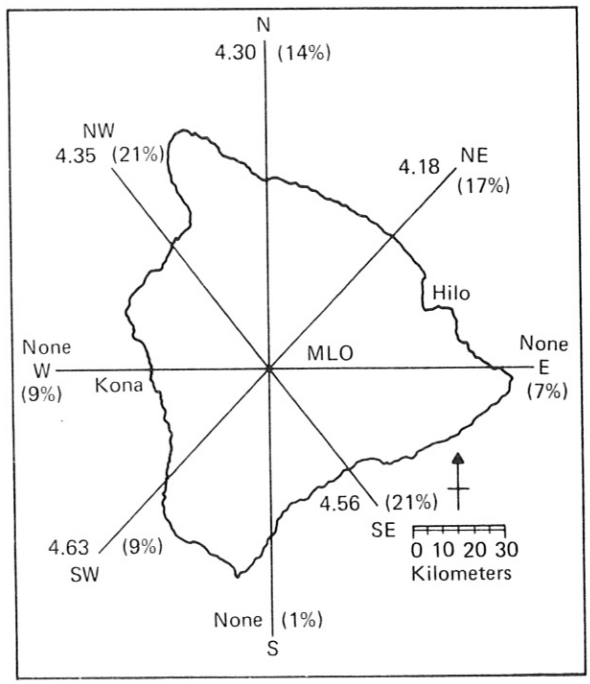


Figure 52. Average weighed pH values for surface wind directions at Mauna Loa Observatory; percent of total precipitation from a given direction is given (June 1975 to Dec 1977).

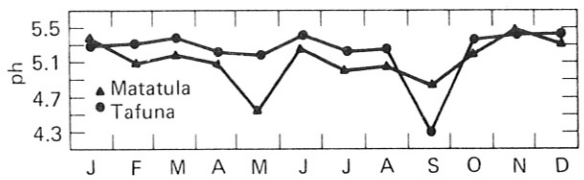


Figure 53. 1977 precipitation pH values from Tafuna and Matatula, Samoa.

4. GMCC SPECIAL PROJECTS

4.1 UV Remote Sensing to Obtain Stratospheric Ozone Concentrations from Surface Measurements

Observations of the vertical distribution of ozone by remote sensing techniques date from 1934 when Goetz et al. (1934) demonstrated that the gross features of an ozone profile could be inferred from the Goetz (1931) Umkehr effect. Not long after, Umkehr observations with the Dobson spectrophotometer were begun at a number of stations located primarily in the Northern Hemisphere. Unfortunately, Umkehr observations were obtained intermittently at most stations, perhaps partly because of the 2 to 3 hours required for a single observation. Nevertheless, several stations have fairly continuous records of long-term observations for 10 to 20 years, and these records have been useful for ozone trend analysis.

The vertical distribution of ozone obtained by the Umkehr technique is derived from characteristics of the height variation of the effective scattering layer (the atmospheric layer where most radiation is scattered). The altitude of the effective scattering layer depends on the strength of molecular scattering and ozone absorption (i.e., on wavelength) and the solar zenith angle. For measurements of solar intensity at fixed wavelengths, as in the Umkehr method, the dependence of intensity on sun angle permits calculation of the vertical ozone profile. This information also can be obtained from measurements as a function of wavelength at some fixed solar zenith angle, a principle used in the Nimbus-4 BUV (Backscattering Ultraviolet) satellite experiment (Heath et al., 1973). However, if both sun angle and wavelength are allowed to vary, greater flexibility is possible for special applications and economy, and the time for an observation can be shortened considerably. An attempt is being made here to develop the latter approach as an alternative to the basic Umkehr technique for measurement of the vertical ozone distribution.

The basic approach is to calculate (using theoretical radiative transfer techniques) the standard Umkehr and Dobson A-C-D-multiple-wavelength (mw) pair response from given ozonesonde profiles of the vertical distribution of ozone. The Umkehr observation is for the C-wavelength pair over the zenith angle range of 60°-90°, whereas the mw observation is for a zenith angle range of 80°-88° (this can be contracted somewhat). The Dobson and mw responses then are compared with the original profiles used in the calculation of the Umkehr and mw responses. Two criteria are used to compare the Umkehr and mw methods; the first involves the root-mean-square-deviation (RMSD) between the solution profiles and the original profiles, and the second is the correlation between the solution profiles and the original profiles. Figure 54 shows the RMSD results, and Fig. 55 shows the correlation results. From the evidence in Figs. 54 and 55, the Umkehr and mw methods are equivalent.

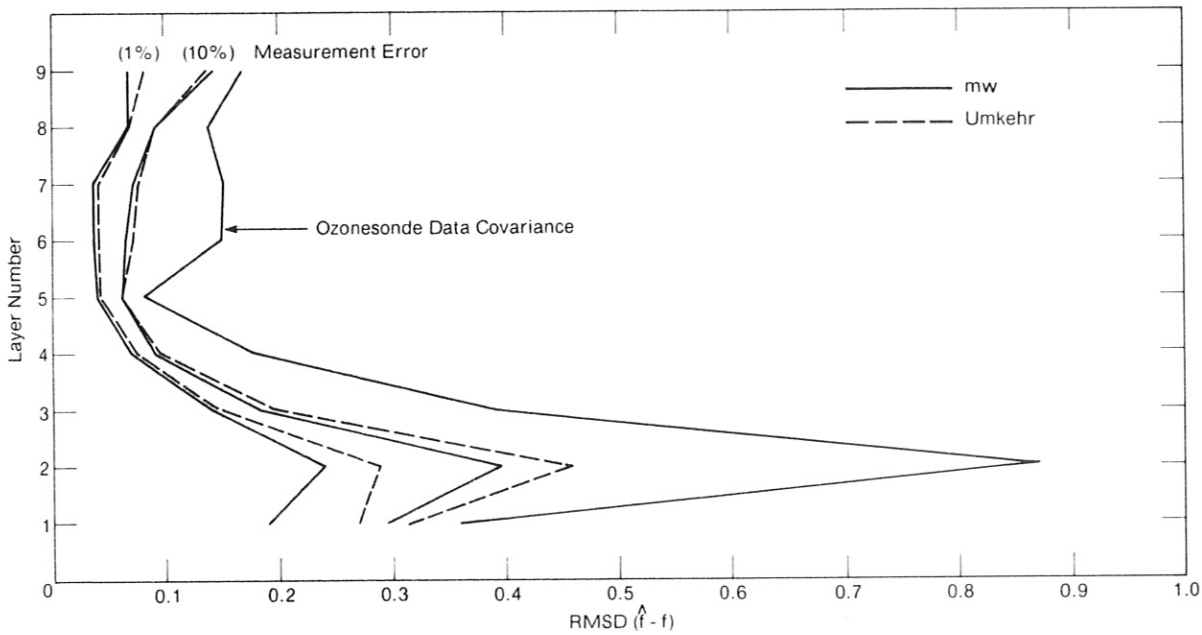


Figure 54. Residual Root Mean Square Deviations connected by straight lines showing results of Umkehr and multiple-wavelength (mw) solutions. Measurement errors of 1% and 10% are shown at the top of each plot. The plot labeled ozonesonde data is the limit at which no new information is available from the measurements. $\hat{f}$ is the solution ozone, and f is the hypothetical true ozone.

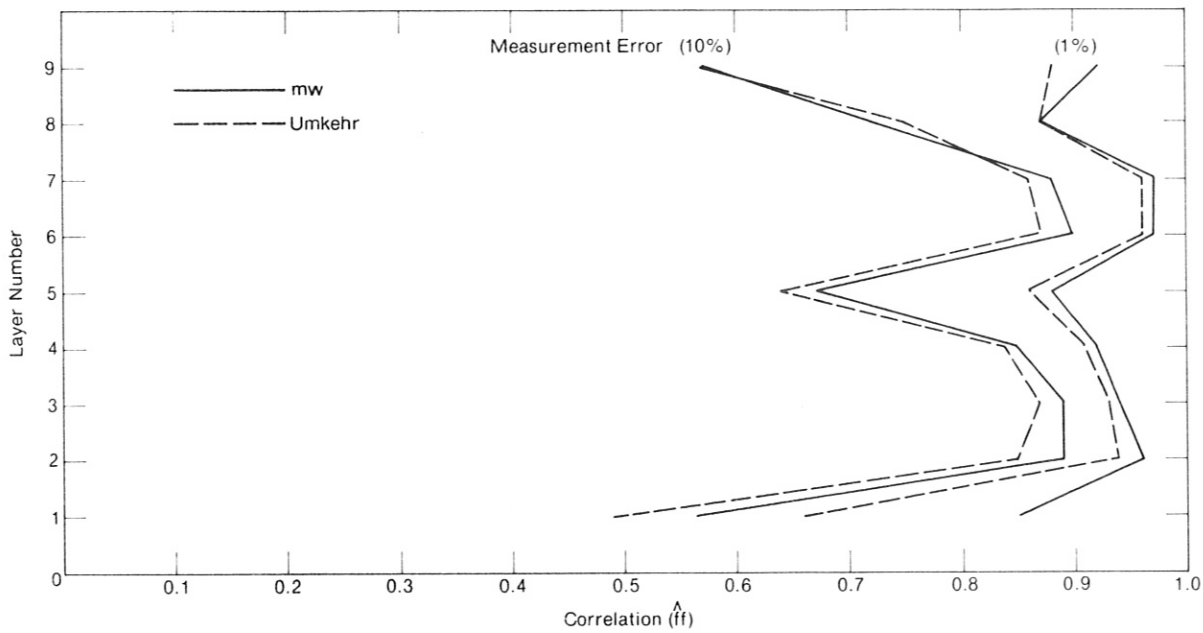


Figure 55. Correlations between $\hat{f}$ (solution ozone) and f (hypothetical true ozone) connected by straight lines. Measurement errors of 1% and 10% are shown at the top of each plot.

The next step is to demonstrate that the mw method will give meaningful ozone profile information from actual observations. A set of ozonesonde, Umkehr, and mw observations, obtained concurrently, are needed for this. A generalized inversion system also must be developed to analyze the mw observations. This work is planned for the near future.

4.2 Analysis of Smithsonian Historical Radiation Data

The Smithsonian Astrophysical Observatory (SAO) measured the solar constant and atmospheric transmission from 1902 to 1957 at fourteen locations on the Earth's surface. Measurements of the solar constant and atmospheric transmission for the period 1923 to 1954 were examined in detail for four stations: Mt. Montezuma, Chile; Table Mountain, Calif.; Tyrone, N. Mex.; and Mt. St. Katherine, Egypt. The objectives were 1) to check for long-term trends in the solar constant or atmospheric transmission, 2) to search for correlations between the solar constant values and atmospheric transmission values, and 3) to provide a long-term baseline of solar radiation measurements at the Earth's surface.

The basic conclusions of the study were these: 1) the solar constant is constant to 0.1% or better over the observation period, 2) the Smithsonian solar constant values vary because the atmospheric extinction by aerosol scattering was not removed correctly in the SAO analysis, and 3) atmospheric transmission of the direct solar beam changed because of volcanic eruptions or local pollution but otherwise appeared constant at the four stations. The Smithsonian observations have been used to identify changes in atmospheric transmission caused by the eruptions of Puyehue in 1921, Reventador in 1926, Paluweh in 1928, Reventador in 1929, and Quizapu in 1932. The results of the analysis of the Smithsonian data are to be published (Hoyt, 1979a; 1979b).

4.3 Measurements of Solar UV Radiation at the Earth's Surface

An exploratory research project to measure diffuse sky and directly transmitted solar UV irradiance on a horizontal surface is in progress at GMCC in Boulder. Instruments used consist of two identical Jarrell-Ash monochromators in tandem with a Peltier-cooled photomultiplier at the exit slit. Wavelength resolution of the measurements is moderate, about 0.001 μm.

Instruments are being evaluated for use in the study of the variability of transmitted UV diffuse and direct radiation, in the wavelength bands that affect tanning of human skin. UV variability is affected by clouds, total ozone, aerosols, surface reflectivity, and solar zenith angle. If an instrument performs satisfactorily it will be used to develop a climatology of spectral UV intensities with emphasis on the erythemal spectral region (about 0.31 μm).

Instruments are sensitive to transmitted UV radiation at wavelengths slightly less than 0.29 μm for small solar zenith angles. Work to improve instrument stability and repeatability characteristics is continuing. Plans for 1978 include comparison of wavelength-integrated measurements with a Robinson-Berger meter and the spectral measurements by the monochromators.

4.4 Urban-Rural Solar Radiation Measurements at St. Louis

In the early 1970's the U.S. Environmental Protection Agency began a comprehensive air quality monitoring program in the St. Louis area to obtain a data base for the development and application of air pollution diffusion models. The heart of this program -- the Regional Air Pollution Study (RAPS) -- was a 25-station monitoring network covering the metropolitan area. Solar radiation instruments were installed at six sites in an approximately north-south line 65 km long, from the southern edge of the urban area to rural countryside north of the city. Eppley pyranometers with quartz, GG22, and RG8 filters and pyrheliometers were placed at four sites; pyranometers with quartz and GG22 filters were placed at two sites. Data were obtained from mid-1975 through March 1977.

In January 1977, ARL/NOAA entered into an interagency agreement with the Department of Energy (DOE) to analyze the St. Louis measurements for urban-rural differences. The principal investigator is J. Peterson in cooperation with T. Stoffel of CIRES. The objective of the project is to process the EPA-archived data, determine the station-to-station variability, and investigate causes for such variability, with emphasis on atmospheric pollution. The analyses will assist the DOE programs in estimating solar collector performance in the urban environment.

Data processing is essentially completed, and analysis is underway. Preliminary indications are that urban pollution is causing depletions of only a few percent of the global incident flux. Station-to-station differences also are being studied according to prevailing meteorological conditions. A clear dependence on north vs. south wind direction is apparent, but dependence on wind speed and prevailing visibility is not evident. A more thorough summary of the initial analyses has been published by Peterson and Stoffel (1978).

4.5 Rehabilitation of United States National Weather Service Pyranometer Data

Since the 1950's pyranometer measurements from the United States network have suffered from accuracy problems. Instrument sensitivities had changed over the years, a complete record of all calibrations did not exist, and the scale of the national pyranometer standards was uncertain. It was recently decided that the quality of the historical

data could be improved by comparing measured irradiance values at solar noon on days with clear skies. Such an approach could determine the combined instrument-recording system response level at any time. Three steps were necessary for this approach: (1) determine clear, solar noon irradiance values, (2) specify the measured (archived) clear, solar noon irradiance values, and (3) adjust the measurements to obtain measured-calculated agreement. Much of step (1) was accomplished in GMCC.

The general approach was (1) to take model calculations of the solar radiation expected at solar noon with clear skies, average water vapor, aerosols, and surface albedo and (2) to modify these calculated values so they are in the best possible agreement with observed irradiance values, which are based on optimum quality measurements and presented on the appropriate radiation scale. As described in the 1975 GMCC Summary Report, a model was developed to calculate theoretical values of global insolation on clear days for the GMCC stations. In 1976, this model was improved to treat atmospheric scattering more realistically and was used to calculate true solar noon atmospheric transmission at 26 locations in the United States. Details of the model are discussed by Hoyt (1978a, 1979c).

The methodology for part (2) of the approach has been described by Hanson (1978). High quality irradiance measurements from Albuquerque, N. Mex., Bismarck, N.D., and Raleigh, N.C., were used to modify the Hoyt calculations. Measurements from these sites also were used to adjust all values to an absolute radiation scale. Finally, at each of the 26 stations climatological values of precipitable water and aerosol scattering were used to obtain model-calculated clear sky, solar-noon irradiances. These "standard-year" results then were used by others to adjust the original network measurements to rehabilitate historical United States pyranometer data.

4.6 Estimation of Short-Term Perturbations to Global Albedo and Temperature Caused by Stratospheric Aerosols from Agung and Subsequent Volcanic Activity

An examination of the Mauna Loa atmospheric transmission record (Mendonca et al., 1978) shows that only recently has the transmission returned to its pre-Agung (1963) condition (see Section 3.8). The volcanic activity that prolonged the decrease in transmission at MLO was measured in both hemispheres. A record of transmission data for Aspendale, Australia, also showed transient variations caused by volcanic activity (Dyer, 1974). Since volcanic aerosols backscatter a portion of the incoming direct solar radiation, the lower atmosphere and surface have been deprived of their solar influx of radiant energy for an extended period of time. In thermodynamic terms this should produce a cooling of the entire Earth.

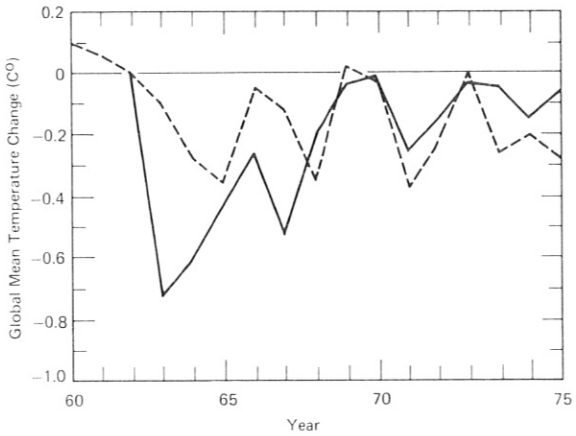


Figure 56. Measured and calculated departure from mean annual temperature (°C), 1961 to 1976. Solid line: calculated (DeLuisi); dashed line: measured (Angell and Korshover).

An investigation was undertaken to estimate the change in the Earth's albedo caused by the volcanic aerosols (DeLuisi et al., 1978). This investigation is unique in its use of a detailed 14-yr record of optical depth and its use of empirically determined backscatter properties of the stratospheric aerosol (DeLuisi and Herman, 1977). The approach virtually eliminated the dependence on assumptions about aerosol size distribution and optical absorption, so often invoked in modeling exercises, to calculate the albedo change.

The change in the Earth's mean radiative equilibrium temperature is calculated on the basis of the Stephan-Boltzman blackbody radiation expression integrated over all wavelengths. Although the results from this simplified approach are uncertain, it produces year-to-year temperature changes of the same magnitude as those from more sophisticated calculations (which also are substantially uncertain).

Figure 56 shows plots of the deviation of annual mean temperature from the global mean for 1962, from the surface to 100 mb, reported by Angell and Korshover (1977), and the radiative equilibrium temperature deviation calculated from the present investigation. The maxima and minima appear to be in phase within ±6 mo (the uncertainty in the time average). A time delay in the radiative equilibrium temperature minima can be introduced by incorporating a global cooling response lag in the radiative temperature calculation procedure. No cause and effect relationship has been established between the two plots at this time.

4.7 Analysis of Raleigh, N.C., Turbidity Data

G. Berri of the Argentine Meteorological Service, Buenos Aires, Argentina, visited GMCC in Boulder, Colo., from August 1 to October 29, 1977. He was supported by a WMO Fellowship. At GMCC, he analyzed the dependence of atmospheric turbidity measurements on air mass trajectories (Berri and Peterson, 1978).

Turbidity observations from Raleigh, N.C., taken with an EPA/NOAA dual-wavelength sunphotometer during 1974, were analyzed. The data were stratified according to the origin of the prevailing air mass. Air mass trajectories were classified into four primary types based on their location within the computational boundaries at the earliest available time (up to 5 or 10 days). The compass was divided arbitrarily into four sectors, such that air flow from each sector would have certain typical characteristics. Sector A includes the approximate northern quadrant from Raleigh. Air masses originating in this sector primarily would have continental polar characteristics, i.e., cool or cold and dry. Air masses originating within sector B (western quadrant) have a long path over the western United States, and, therefore, are typically dry, because of their continental trajectory, and warmer than type A, because of a western rather than northern origin.

The boundary between sectors B and C (a line from Raleigh to the northwest edge of the Gulf of Mexico) separated continental from maritime air flow. Air masses at Raleigh that originated within sector C typically had maritime tropical characteristics, i.e., warm or hot and moist. The C-D sector boundary was drawn arbitrarily due east from Raleigh to separate North and South Atlantic airflow. Although air from either sector would be moist, the more northerly origin usually would be cooler, especially during winter.

The analyses of atmospheric turbidity at Raleigh, N.C., as a function of air mass trajectories yielded several interesting results. First, during all seasons turbidity is largest with southerly air flow. For each season, turbidity associated with type C trajectories (Fig. 57) averaged about 1.5 times that with type A trajectories. Second, for both trajectory types B and C, the turbidity increase as a function of air mass travel time over the eastern United States was markedly greater during summer than winter. This was more pronounced for type C trajectories.

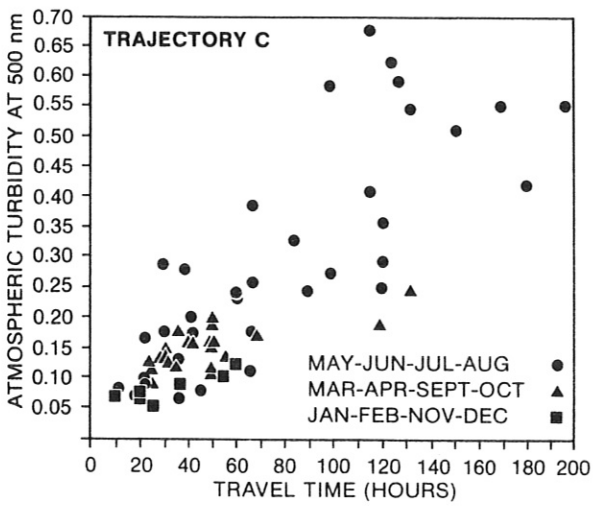


Figure 57. Decadic turbidity coefficient (500-nm wavelength) at Raleigh, N.C., as a function of travel time (hours) from the Atlantic or Gulf of Mexico coast to Raleigh. Data are stratified by season.

Third, the overall turbidity increase averaged about 0.10 units for each 100 h of travel time, except for type C trajectories during summer, which averaged about 0.29.

4.8 Cloud Cover Studies

The climatology of cloud cover over the globe, the meaning of cloud cover, and the year-to-year variations of cloud cover have been investigated over the past several years. The discrepancy between satellite measurements and theoretical calculations of the albedo of the tropics was attributed to errors in cloud climatology (Hoyt, 1976). Hoyt (1977a) investigated this discrepancy by using sunshine recorders and pointed out that cloud cover has two definitions in the literature but the differences between these are not recognized generally.

Total cloud cover was deduced from measurements of the percent of possible sunshine at 72 locations in the United States. This sunshine-derived total cloud cover was compared with conventional ground-based observations of total cloud cover made by meteorological observers. On the average the sunshine-derived values of total cloud cover were about 13% lower than the corresponding ground-based estimates of total cloud cover. This difference may be attributed to two types of projection problems: the ground-based observers may view sides of clouds and add them to the estimate of total cloud cover, or the sunshine recorders may fail to detect thin cirrus clouds. The difference between sunshine-derived and ground-based estimates of total cloud cover as a function of latitude indicates that ground-based observers have difficulty estimating total cloud cover. A more standard definition of "cloud" and "total cloud cover" is needed for radiation budget and climate modeling studies. These definitions were further clarified by Court (1978) and Hoyt (1978b).

Some implications of the use of the cloud cover climatology to understand climate change were discussed by Hoyt (1977b) in a comment on an article by Cess (1976). Interannual cloud cover variations were studied along with their effects on measurements of global insolation from year to year (Hoyt, 1978c). Mean interannual cloud-cover variations at 103 locations were calculated from sunshine recorder data for the contiguous United States. A typical location has a mean, absolute, year-to-year cloud cover variation of 3.95% that corresponds to a variation of about 14 overcast days per year and to about a 2.8% variation of the annual mean global insolation. As a consequence of these natural variations, about 30 years of sampling would be needed to determine the annual mean cloud cover to an accuracy of 1% with 95% confidence. Regional year-to-year variations are smaller than those at individual locations, and, for the entire contiguous United States, cloud cover variations average 1.2%. Theory suggests that on hemispheric and global scales the interannual variations in total cloud cover are very small, about a few tenths of a percent.

4.9 Observational Verification of the Effect of Haze on the Vertical Distribution of Ozone Deduced from the Umkehr Technique

The explosive eruption of Mt. Agung in 1963 produced an increase in the bimonthly mean aerosol optical depth over Australia of about 0.15 at wavelengths of solar emission maximum (DeLuisi and Herman, 1977). A shorter term perturbation following the eruption could have been almost twice as large (Pollack et al., 1976).

Examination by DeLuisi (1978) of the vertical distribution of ozone determined by the Umkehr technique for the 11-year Aspendale record from 1962 to 1972 revealed a large apparent change in concentrations in the upper (>35 km) and lower (<20 km) stratospheric levels immediately after the Agung event. In the upper levels the concentrations decreased about 40% below the climatological average whereas the lower level concentrations increased by about 65%. However, no significant change in the total ozone as determined from conventional Dobson measurements was seen before, during, or after the Agung event, indicating that total ozone concentration throughout the vertical was normal. Thus, the upper and lower stratospheric changes were apparently fictitious, resulting from an aerosol influence on the Umkehr method.

Figure 58 shows the fictitious change to the Umkehr ozone profile (labeled empirical) from values normally expected during June-July and August-November. Layers 1 to 9 correspond to the standard pressure levels of the 9-layer Umkehr model: 1000, 250, 125, 62.5, 31.3 15.6, 7.8, 3.9, and 1.95 mb, respectively. The Aspendale data are empirically derived fictitious changes. At the bottom of Fig. 58 are the normalized standard deviations of ozone concentrations determined by the Unkehr method for each layer.

To investigate this fictitious change, a theoretical model of the Umkehr technique was developed that incorporated the effects of aerosols. Three different vertical distributions of aerosols were used. Aerosols in Model I are primarily tropospheric, in Model II partly stratospheric and partly tropospheric, and in Model III primarily stratospheric. Aerosol optical depths for these models are drastically different. The stratospheric aerosol optical depth in Model III is approximately 0.03 whereas the tropospheric optical depth in Model I is 0.30. Theoretical calculations of the fictitious change (error) in the vertical Umkehr ozone profile are also shown in Fig. 58. The error effect on the high-level ozone (layers 8 and 9) is nearly the same from the large tropospheric aerosol amounts as from the small stratospheric amounts. These results emphasize the great error sensitivity of the Umkehr method to stratospheric aerosols. From a comparison of the theoretical and empirical results it appears that Agung aerosols were prevalent in the troposphere (thus producing the low-level error) as well as the stratosphere soon after the eruption.

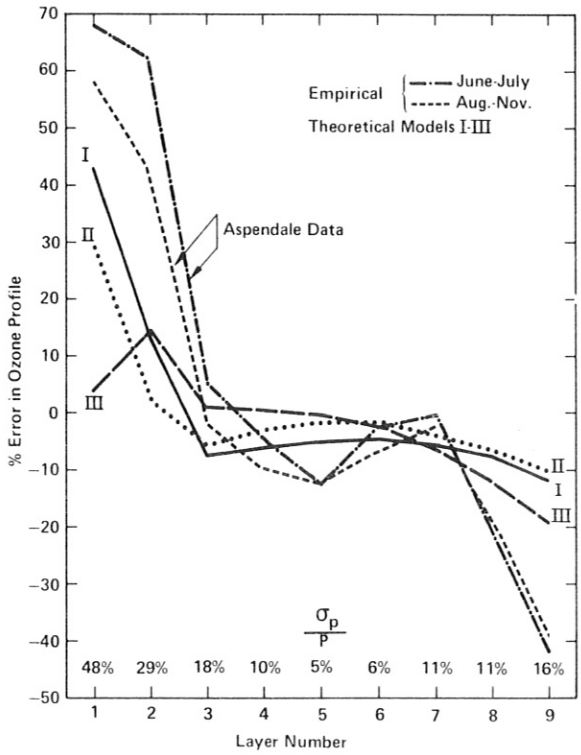


Figure 58. Fictitious change to mean vertical distribution of ozone due to tropospheric and stratospheric aerosols.

In an analysis of ozone trends in the stratosphere Angell and Korshover (private communication) found a transient decrease in Northern Hemisphere upper stratospheric ozone concentrations shortly after Agung. Otherwise, their analysis indicates a trend toward increasing concentrations during the 1960's. The results of this study can be used to show theoretically that the transient ozone decrease was fictitious because of the effect of aerosols on the Umkehr technique where Mauna Loa direct solar beam transmission data were used to quantify the stratospheric aerosol optical depth changes for the Northern Hemisphere.

4.10 GATE Surface Radiation Measurements

The NOAA Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE) project office is supporting a GMCC effort to reduce and analyze the United States GATE radiation measurements. The GATE program was conducted from 15 June through 23 September 1974 between 0° and 20° N latitude in the Atlantic Ocean. A main objective of GATE was to evaluate the influence of the tropical atmosphere and oceans on the global circulation. Seventy nations supplied equipment and manpower, including 39 research ships, 13 aircraft, 10 satellites, and almost 4000 scientists and technicians.

Five U.S. ships with fixed positions during GATE were used as platforms for solar and infrared radiation sensors. Four of the ships deployed a boom over the bow of the ship to provide the best sensor exposure with the least influence from the ship. Upfacing and downfacing Eppley pyranometers and a Swissteco net radiometer were mounted at the end of the boom. The boom-mounted radiometers were monitored continuously (sampling rate 0.5 s) by the Shipboard Data System (SDS). Volz-type sun photometers and normal incidence pyrheliometers, both made by Eppley, were tripod-mounted on the decks of the four ships.

Personnel on the Oceanographer maintained two Eppley model 15 pyranometers with WG-7 and RG-8 hemispheres, respectively, mounted on the top of the instrument shelter on the ship's bow. On the fifth ship, downward global and direct solar irradiance were measured.

During 1977 a report was prepared to familiarize the scientific community with the United States B-scale shipboard radiation data (Cram and Hanson, 1977). The report describes the instruments, processing methods, and quality of radiation data collected by United States ships. The appendices contain tables of data collected aboard U.S. ships, including microfiche copies of 3-min and hourly averages of SDS-recorded data (incoming and reflected solar radiation, net radiation, and sea-surface temperature).

Plans for this project are to calculate the distribution of radiative energy components (short wave and long wave) over the GATE experimental area. The ship-based data will be combined with satellite measurements for these computations.

4.11 ARL-Estes Park Workshop on Monitoring the Solar Constant and Solar UV

Neither of the two conferences on solar variability held in the past few years established scientific criteria for solar monitoring based on answers to these questions: what is needed for climatology research; what is technically possible; and what combination of integrated spacecraft, rocket-, and surface-based monitoring is logical. Because of the need for criteria on solar monitoring, GMCC organized a workshop at Estes Park, Colo., from 8 August through 12 August 1977. Solar and atmospheric physicists, climatologists, and specialists on radiant energy measurement instrumentation attended. NASA, NBS, NOAA, private industry, and universities were represented at the workshop. The variety of scientific backgrounds of the conference participants attested to the interdisciplinary need and nature of this gathering.

4.11.1 Workshop Organization and Sessions

Background papers were presented on the following topics: solar variability, modeling climate change and chemical change in the terres-

trial atmosphere caused by a variable sun, observational evidence of such changes, and current technology available for measurement of solar emissions. These papers provided a broad overview of the solar variability-climate problem and a basis for the panel sessions during the latter half of the workshop. After the presentation of background papers, an open session allowed participants to present views, issues, and research results relevant to the workshop.

During the second phase of the workshop, four panels of experts dealt with specific aspects of the monitoring problem: atmospheric and climatic effects, solar variability, monitoring the sun from space, and monitoring the sun from within the Earth's atmosphere. A plenary session on the final day of the workshop allowed each panel to present its views and conclusions to the entire group. This session also provided a final opportunity for participants to present their thoughts on relevant topics not previously introduced or incompletely discussed during earlier sessions.

A workshop report prepared by panel members and the organizing committee is available (Air Resources Laboratories, 1978).

4.11.2 Principal Conclusions of the Workshop

Scientific

(1) More and better information on solar variability on all time scales is needed if the solar effects on climate are to be understood more completely.

(2) The quantities monitored should include total and spectral solar irradiance, particle flux, and magnetic fields. (Specification for these measurements developed in the panel discussions are presented in Section 4 of the report). Comprehensive monitoring and accompanying research programs should be developed.

(3) Although solar variability may occur on all time scales, a comprehensive monitoring program should be continued for at least one 22-yr solar cycle, with the provision that a less vigorous but much longer monitoring program may be needed to detect variability on longer time scales.

Technological

(1) Greatly improved primary and transfer radiation standards are needed to achieve absolute accuracy and maintain accuracy of calibration transfer to field instruments over the 22-yr period envisioned for the monitoring program. Complete documentation of the calibration procedures also is necessary.

(2) The requirements for absolute and relative accuracy presented by the Atmospheric and Climatic Effects Panel have not yet been met in field measurements of spectral irradiance; in fact, they have been approached only by a few investigators in the laboratory. They are considered within reach in the field within the next few years, but research in instrument construction and absolute standardization is needed.

(3) At least three high-altitude sites should be established for surface-based monitoring. Experience at the Mauna Loa Observatory shows that it is an excellent site. The second site should be chosen from existing high-altitude observatories in the southwestern United States to facilitate the early instrument-development program. The choice of a third Southern Hemisphere site would minimize seasonal atmospheric interference.

(4) The ground-based monitoring program will require atmospheric corrections to obtain the desired solar data. To assure that such corrections are of the highest quality, concurrent measurements of atmospheric temperature, pressure, and water vapor as a function of height, total atmospheric ozone, turbidity, and solar aureole should be made.

(5) The quality of the solar observations will depend on extreme care in the use of high-precision instrumentation and in analysis of the measurements. All instrumental characteristics and calibrations should be evaluated and accurately accounted for in data reduction. Systematic intercomparisons between the satellite- and surface-based observations are necessary to assure the highest quality control of the measurements.

(6) Early provision should be made for prompt and open dissemination of solar monitoring data to interested users and for its archiving. The workshop did not decide what data should be archived, an important matter that needs study. The NOAA World Data Center or the NASA NSSDC should be funded to support data archiving.

(7) The need for measurements for long-term solar monitoring and the need to observe impulsive forms of solar variability require that satellite-based observations be made from a solar-pointed platform.

5. DATA MANAGEMENT

5.1 Data Acquisition

During January, all GMCC measurement equipment at Amundsen-Scott Station, South Pole, including the Instrument Control and Data Acquisition System (ICDAS), was moved from the temporary, undersnow structure (occupied for the previous two years) to the Clean Air Facility. This new building provides superior environmental control and thus all electronic components show less thermally-induced drift. The space is adequate for proper maintenance and repair. No data were taken for the 13 days of moving.

The relatively frequent failure of the ICDAS at Mauna Loa Observatory in preceding years was traced, in part, to its housing in an uninsulated metallic building at 3.4-km altitude, and inadequate space for maintenance and repairs. The ICDAS was finally returned to Boulder in the spring for a complete overhaul. It was returned to MLO and installed in the new building in July and has since operated with little difficulty. The new configuration of the ICDAS is shown in Fig. 59.

The ICDAS at the four stations was on line slightly more than 80% of the time on the average. The distribution of on-time for each station is shown in Fig. 60.

All the hardware components were purchased to complete the construction of the prototype version of the interface between the digital access electronics (CAMAC crate) and the NOVA minicomputer. The complete circuit is to be completed early in 1978. D. Williams was contracted to write software (CALL subroutines) and to modify the executive program to transfer data through the digital port into the data base. Work was completed on a prototype version of the digital interface to the surface ozone instruments.

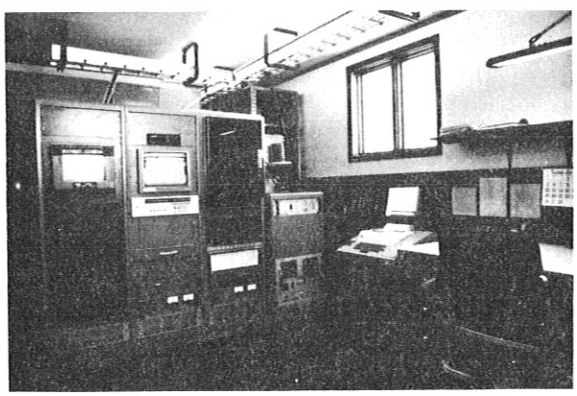


Figure 59. ICDAS and associated electronics in the Clean Air Facility at the Amundsen-Scott Station, South Pole, Antarctica.

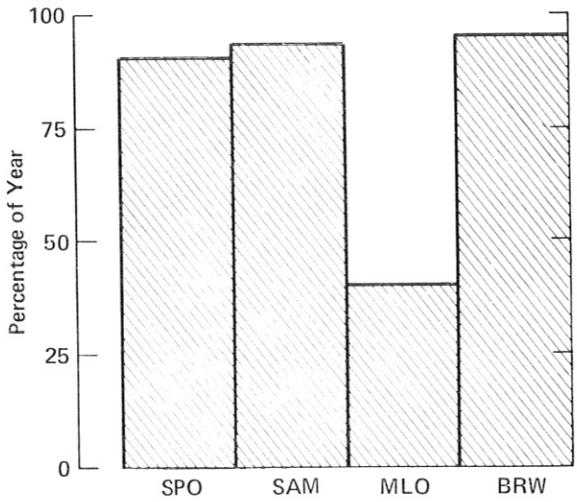


Figure 60. The percentage of time the ICDAS was in operation at the four GMCC stations in 1977.

The executive program used in 1976 had two major problems: the need for a simplified restart sequence and for better accounting for calibration factors. A new executive program was structured to find the most recent calibration record and reinstate that information in core. Only very minor changes were made to the structure or content of the data base. The ability to log plain language statements on the data tape without interrupting the normal flow of data was added to the program as was a complete evaluation of the weekly calibration of the carbon dioxide analyzer, the printout from which provides the information to evaluate the accuracy of the calibration while it is in progress. The new executive, BOSS 77280, was installed at all stations by mid-December.

5.2 Data Reduction

Data tapes from the observatories are routinely sent to Boulder for reduction and processing. The Boulder data reduction facility is shown in Fig. 61.

Figure 61. Boulder data reduction facility. A tape from a GMCC observatory is being processed by J. Harris, L. Johnson, and A. Bottomly of the GMCC Acquisition and Management Group.

5.2.1 System Software

The support software has been greatly improved. New BASIC commands and CALL subroutines have been added to permit full use of the peripherals, and errors in both the interpreter and the subroutines have been corrected. In addition, software now provides data compatibility between Data General's BASIC and FORTRAN so that either programming language can be used in the reduction of the data.

New BASIC commands include the following:

WRITE performs the same function as PRINT, but directs output to the Centronix high-speed printer.
SYS exits BASIC, gives control to DDOS (Decision Disk Operating System).
SAVE XXXX saves the BASIC source program on an ASCII disk file named XXXX. In this form the program may be loaded back in (see next command) or edited with the DDOS Editor.
LOAD XXXXX loads a disk file of a BASIC source program into core. With LOAD and SAVE, only one copy of the BASIC interpreter and the CALL subroutines is necessary to run many different BASIC programs, thus saving space on the disk.

Additional CALL subroutines include the following:

CALL 38, UØ changes tape drive unit to the number in UØ. This routine allows easy switching from one tape drive to the next and from NRZI (800 BPI) mode to PE (1600 BPI) mode.
CALL 40, SØ tells the number of bytes in the TTY buffer, allowing the program to check for operator requests without stopping the processing of data.
CALL 49 and 45 are improved versions of CRT plotting routines.
CALL 50,N,A are plots on the line printer.

The CALL subroutines can now access up to four disk files at once, and read and write ASCII data files, which, unlike BASIC floating point files, can be read directly by FORTRAN programs.

Two major problems stood out in the system software: (1) The tape read-write routine was reading 8 bits more than requested and sometimes overwrote other data in core. (2) Data were incorrectly buffered out to the CRT, causing overprinting or garbling. These two problems have now been corrected.

5.2.2 Processing Software

There are now four main programs for the reduction of ICDAS data. These programs are all run on the NOVA minicomputer and serve three major purposes: (1) to allow the operator a quick look at the data tapes to determine as soon as possible if there are any outstanding

hardware or software problems; (2) to provide documentation of the data tape; (3) to get the data in a form usable at the NBS computer facility.

The first program, "Station Data Inventory," runs on every 10-day station tape. It existed before 1977, but has been expanded and improved. It checks the format and sequence of records on the tape, checks the primary calibration constants, and reports messages from the operator, some performance parameters of the system, and periods of missing data. Part of the output is sent back to the stations with a printout of the hourly averages.

The second program produces a printout of hourly averages directly from the D array (no rescaling performed). One copy is sent to the stations, and one is kept in Boulder. This program was modified in 1977 to speed up turnaround. Changes in the channel configuration and the BOSS allowed us to generalize one program to process data from all four observatories.

"TAPE COPY," the third program, copies the 10-day NRZI tapes onto a monthly PE tape and corrects any format errors (e.g., EOF's among data recorded, two identification records adjacent to one another, parity errors, etc.). It also corrects sequence errors caused by clock failure or faulty tape positioning and errors in the information appearing in the first 16 locations of the Identification or I Array (e.g., wrong station ID). The tape is readable and usable by programs at the Boulder computer facility.

The fourth program, "ICERT," checks the newly created monthly tape for format, sequence, parity, and I array errors; it gives a listing of errors (if any), and a 2-page table showing missing records during the month. If any errors appear, the tape is recreated correctly.

5.3 Data Processing

The processing phase of operations occurs as the project leaders display, edit, and certify their data and before any official distribution of data. Generally, the CDC 6600 is used rather than the minicomputer, because of the high density of the data and the amount of computation required. The main challenges in data processing were (1) accessing the data on the CDC 6600, (2) displaying the data in convenient forms, and (3) developing editing procedures for elimination of bad data points, change in calibration factors, and fill-in of missing data.

Originally, we planned to work directly with the 10-day station tapes on the CDC 6600, but continual problems in reading them, because of formatting, sequencing, or read parity errors, forced us to recopy each station tape onto a phase-encoded monthly tape. The monthly tapes are much more reliable and convenient than the 10-day tapes.

In late 1977, new 9-track tape drives from Storage Technology Corporation were installed. In 1978, we will copy the monthly tapes to "internal" CDC 6600 tapes (in the NOAA/ERL computer library) and the monthly tapes will be returned to the reduction facility. The internal tapes will be more reliable and easier to read. Higher quality tapes (6250 BPI certified) are now furnished by the storeroom.

The second challenge was data display. In the past we relied heavily on tabular printouts of hourly average values, but for the solar radiation program, for example, hourly averages could not be used to detect subtle problems such as interference from a tower, tilting of the domes, or slow degradation of the filters. To certify and edit data before archiving them, and to check on instrument performance, a program was written to graph 2-minute averages of the quartz and four filter-pyranometer signals. The theoretical values for extraterrestrial irradiance are plotted as well, as an upper limit of valid values from the pyranometers. One frame per day is produced with data plotted in units of kilojoules m^{-2}. A second plot for the day gives the ratios of quartz pyranometer to global extraterrestrial values and filter-pyranometer to quartz values. Various graphing routines were written to display aerosol and meteorology data. In 1977 graphing of data was improved by acquiring a high quality CRT which can be used for interactive graphics. Another aid is a new set of system graphics routines.

Some new procedures were developed for editing ICDAS data. Data editing now consists of changing calibration constants and rescaling the data, supplying data from other sources such as chart records to fill gaps in the ICDAS record, or eliminating bad data points. The solar radiation and CO_2 editing programs have been modified to accept new calibration constants. The voltages from the solar radiation instruments, for example, are converted to energy units using a "night-time" offset, a preamplifier offset and gain, and the pyranometer calibration constant.

The use of disk files and the "Telex System" makes possible interactive editing and inspection of the data. Both aerosol and meteorology data were pulled off the ICDAS tapes onto separate disk files. These files were then accessed in real-time by means of the Telex Editor. Deletions and corrections were made both interactively and through programs that ran with the disk files. Data from sources other than ICDAS were merged with the original files to obtain more complete data sets. Missing or incorrect data were eliminated by putting all nines in the field.

5.4 Data Distribution and Archiving

Data in the form of tabulated hourly averages are distributed to the stations where they are used to check the performance of individual sensors and to answer questions about specific measurements from visi-

tors and cooperating scientists. These data receive no review or editing and are considered preliminary. During the year such data were issued routinely to the Mauna Loa Observatory and to the Samoa Station.

On June 22, 1977, a tabular listing of carbon dioxide flask data from 1968 through 1975 was sent to the World Data Center A in Asheville, N.C., for publication in "Global Monitoring of the Environment for Selected Atmospheric Constituents."

On December 9, 1977, a magnetic tape containing 3 years (1974-1976) of nephelometer data for Mauna Loa was sent to Asheville for archiving. The tape name is MLONF1, and it is located in Deck No. 9708 in the Computer Products Branch, FTS 672-0203 or 704-258-2850, ext. 203.

6. COOPERATIVE PROGRAMS

6.1 Atmospheric Electric Measurements at Mauna Loa Observatory

William E. Cobb

NOAA, Atmospheric Physics and Chemistry Laboratory
Boulder, CO 80302

The measurement phase of the atmospheric electric program at Mauna Loa Observatory has been completed. The project has been a cooperative effort of GMCC and NOAA's Atmospheric Physics and Chemistry Laboratory. A data set consisting of average hourly values of the electrical conductivity, potential gradient, and air-earth current density has been completed for all fair-weather days at Mauna Loa for the period October 1975 to April 1977 and is available for further analysis and interpretation.

These latest results represent the third intensive measurement interval of electrical parameters at the observatory since 1960. The purpose, as with the earlier measurements, has been to obtain a reproducible data set that represents an environmental benchmark at a site where the atmosphere is representative of the global or at least the subtropic Pacific atmosphere.

The physical basis for the correlation between the atmospheric electrical conductivity and the amount of airborne particulate matter is now well understood and verified. The suspended particulates provide surfaces upon which the conduction ions of the atmosphere diffuse to become immobilized or recombined, thus leading to a measurable loss in conductivity which persists as long as the pollution exists. Even at a clean-air site such as Mauna Loa we must interpret the measurements both as a response to global variations in the atmosphere's electrical system and as effects produced within the local environment. Electrical measurements at low-level land sites are dominated by the local environmental conditions as a result of the injection of particulate matter into the lower air strata and of continuing but irregular convective and diffusion processes. The advantage of measurements at Mauna Loa is that they permit us to evaluate the electrical properties of the atmosphere above the exchange layer and the tradewind inversion in such a way that secular variations can be interpreted relative to alterations in the global level of suspended particulates.

Electrical measurements at Mauna Loa are subject to local influences, mostly as consequences of the diurnal wind regime. Periods of local contamination can usually be identified in the data record. However, the problem has become more serious since July 1975 when a brief eruption of Mauna Loa ended a quarter century of dormancy. Some gaseous effluent has existed in the summit caldera of the volcano since

the observatory's construction, but this is insignificant compared with the visible smoke now emanating from a new fissure directly upslope and near the summit of Mauna Loa. Unfortunately, this local pollution at the observatory is most likely to have an effect during the nocturnal downslope wind periods when the cleanest, most globally representative air samples have previously been obtained.

A notable feature of the measurements made in 1960 and 1968 is the stable atmospheric electric conditions during downslope winds, with the recorded data often appearing as straight lines on recorder strip charts. In the most recent measurement period it is unusual to find a nighttime record whose electrical parameters are not disturbed to some extent, presumably by the injection of particulates into the shallow downslope wind, which is a predominant feature of the local climatology. The discontinuities in the normally stable nighttime records appear to be caused by bursts of aerosols. These always decrease the conductivity, in a manner similar to what one might expect at another location from passing automobiles or cigarette smokers near the air intakes. Obviously, the wind direction and turbulent mixing processes determine to what extent and in what concentration the pollution from an essentially point source on a very large mountain arrives at the observatory.

Sporadic occurrences of locally produced aerosol pollution can be identified on the data records of several continuously monitored parameters at Mauna Loa Observatory. The atmospheric electric measurements, particularly the conductivity, are especially valuable for detecting the presence of polluting aerosols.

In summary, it appears that the conductivity decrease that frequently occurs during downslope wind conditions is almost certainly due to volcanic smoke particles from recently increased venting. It can be stated that the electrical conductivity, monitored in fair-weather at Mauna Loa and with those periods affected by volcanic smoke eliminated, has not been significantly altered from identical measurements made in 1960 and in 1968. Because of the correlation between conductivity and aerosols, it can also be assumed that the background particulate burden at Mauna Loa has remained stable since 1960.

6.2 Sunburning Ultraviolet Meter

Daniel Berger

Temple University
Philadelphia, PA 19140

The GMCC Mauna Loa Observatory is one station of the Sunburn Ultraviolet Meter network which has supplied data since 1973. The data consist of the dose of sunburn-effective ultraviolet (wavelengths shorter than 320 nm) received on a flat detector each half hour. The network was expanded by five stations in 1977. At year's end 23 stations were in operation with calibrated, interrelatable results (Table 21). Five more stations are expected to be established in 1978.

Table 21. Network of Stations Measuring Ultraviolet Radiation with the Sunburn Ultraviolet Meter

Sunburn Ultraviolet Stations	Period of Continuous Operation
Bismarck, N. Dak.	Oct 1973 - present
Tallahassee, Fla.	Sep 1973 - present
Oakland, Calif.	Oct 1973 - present
Fort Worth, Tex	Sep 1973 - present
Minneapolis, Minn.	Oct 1973 - present
Des Moines, Iowa	Oct 1973 - present
Albuquerque, N. Mex.	Sep 1973 - present
El Paso, Tex.	Sep 1973 - present
Mauna Loa, Hawaii	Dec 1973 - present
Philadelphia, Pa.	Sep 1973 - present
Honeybrook, Pa.	Nov 1974 - present
Detroit, Mich.	Sep 1977 - present
Seattle, Wash.	Sep 1977 - present
Salt Lake City, Utah	Oct 1977 - present
New Orleans, La.	Sep 1977 - present
Atlanta, Ga.	Oct 1977 - present
Tucson, Ariz.	Jun 1975 - present
Belsk, Poland	May 1975 - present
Warsaw, Poland	Jun 1975 - Sep 1976
Aspendale (Melbourne), Australia	Jun 1974 - present
Brisbane, Australia	May 1974 - present
Davos, Switzerland	Oct 1974 - present
Hamburg, Germany	Feb 1976 - present

Computerization of network data was considerably advanced this year, so that data printouts and calibration corrected data can be more quickly and conveniently obtained. Software for a computer compatible output was developed and installed at three stations. This output is in addition to the half hourly printout of sunburn effective UV.

The National Oceanic and Atmospheric Administration is responsible for storing data from all stations in a computer and making the results available. Most of the information up to December 1976 has been computerized. Data were recorded 97% of the time during 1977, continuing the previous high reliability of the data acquisition system.

Recent publications utilizing measurements from the network include those by Green et al. (1976), Berger (1976), and Scotto et al. (1976).

6.3 Smithsonian Solar Monitoring Program at Point Barrow, Alaska

W. H. Klein and B. Goldberg

Smithsonian Institution
Rockville, MD 20852

The solar radiation monitoring program of the Smithsonian Radiation Biology Laboratory at Point Barrow, Alaska, is continuing to provide baseline measurements of ultraviolet, visible, and infrared short-wave solar radiation at the earth's surface. The instrumentation has been described by Klein et al. (1977).

The data from Barrow, Rockville, and Panama show significant differences in spectral quality as well as quantity of sunlight. Measurements through 1975 have been published by Klein and Goldberg (1974, 1976). Although regressions were run to determine trends in the spectral variations at Barrow (Goldberg and Klein, 1977), a better overview of the spectral variations was determined with a very simple model (Goldberg and Klein, 1978). The model predicts hourly and daily totals of global irradiances on a clear day quite well, as shown in Table 22. The variability from place to place is readily seen in Table 23. At each site, the relationship between irradiance of a spectral band and the total global irradiance is consistent when values are averaged over several years. However, this long-term relationship may not be valid for every day of the year.

Ultraviolet B energy also has shown marked effects due to variations in total ozone thickness (Klein and Goldberg, 1978). A change of 5 nm in the shortest detectable wavelength occurs for each 30° change in latitude so that at Panama (9°N) it is 290 nm, at Rockville (39°N) it is 295 nm, and at Barrow (71°N) it is 300 nm. The data indicate that ozone may be the principal determinant of the short-wave transmission of the atmosphere, but the amount of ultraviolet B energy received at the earth's surface is strongly influenced by meteorological conditions.

Table 22. Predicted (P) and Observed (O) Hourly Total Global Irradiance (cal cm^{-2}) in Various Wavelength Bands at Barrow, Alaska (71°N), 8 April 1974

Hour of day*	Total Spectrum		400-500 nm		500-600 nm		600-700 nm		700-800 nm		800-2800 nm		400-700 nm	
	P	O	P	O	P	O	P	O	P	O	P	O	P	O
5-6	0.62	2.10	0.11	0.42	0.09	0.24	0.08	0.24	0.05	0.12	0.28	0.90	0.27	0.90
6-7	5.66	7.56	1.03	1.38	0.78	0.84	0.68	0.84	0.45	.54	2.55	3.48	2.49	3.06
7-8	13.42	14.46	2.43	2.82	1.85	1.50	1.62	1.74	1.07	1.26	6.05	6.60	5.91	6.06
8-9	21.49	22.20	3.90	4.02	2.97	2.82	2.59	2.70	1.71	1.98	9.70	9.90	9.46	9.54
9-10	28.71	28.74	5.20	5.46	3.97	3.54	3.46	3.72	2.28	2.52	12.95	12.84	12.63	12.78
10-11	34.33	34.14	6.22	6.36	4.75	4.41	4.14	4.46	2.73	2.92	15.49	15.06	15.11	15.24
11-12	37.88	37.59	6.87	6.81	5.24	5.05	4.57	5.02	3.01	3.20	17.09	16.49	16.67	16.87
12-13	39.02	38.63	7.08	6.71	5.40	5.41	4.71	5.11	3.11	3.42	17.63	16.85	17.19	17.23
13-14	37.79	37.37	6.85	6.29	5.22	5.48	4.56	4.96	3.00	3.22	17.05	16.46	16.63	16.73
14-15	34.16	34.11	6.19	5.67	4.72	5.00	4.12	4.42	2.72	3.28	15.41	14.89	15.04	15.09
15-16	28.47	28.94	5.16	5.08	3.94	4.01	3.43	3.71	2.26	2.75	12.85	12.78	12.53	12.80
16-17	21.21	21.94	3.85	3.78	2.93	3.11	2.56	2.69	1.69	2.09	9.57	9.93	9.34	9.58
17-18	13.13	14.68	2.38	2.39	1.81	1.92	1.58	1.95	1.04	1.43	5.92	6.78	5.78	6.26
18-19	5.41	7.51	0.98	1.16	0.75	1.01	0.65	0.96	0.43	0.714	2.44	3.57	2.38	3.14
19-20	0.56	1.88	0.10	0.37	0.08	0.27	0.07	0.30	0.04	0.28	0.25	0.70	0.25	0.94
Daily Total	321.91	331.97	58.36	58.77	44.49	44.66	38.82	42.86	25.59	29.84	145.24	147.26	141.67	146.35

*Sunrise was at 0445; sunset was at 2018.

Table 23a. Average Extinction Coefficients (τ) Calculated From Clear-Sky Data

Site	Total Spectrum	400 nm-500 nm	500 nm-600 nm	600 nm-700 nm	700 nm-800 nm	800 nm-2800 nm	400 nm-700 nm
Barrow, Alaska	.056	-.037	.020	.038	.144	.105	-.010
Rockville, Md.	.144	.002	.065	.118	.190	.188	.055
Washington, D.C.	.144	.028	.112	.034	.316	.173	.055
Panama	.198	-.053	.101	.012	.339	.302	.020

Table 23b. Average Percentage of Total Irradiance on a Horizontal Surface

	400 nm-500 nm	500 nm-600 nm	600 nm-700 nm	700 nm-800 nm	800 nm-2800 nm	400 nm-700 nm
Barrow, Alaska	18.79	15.29	13.62	9.24	39.04	47.77
Rockville, Md.	17.14	15.86	12.24	10.31	41.05	45.24
Washington, D.C.	16.80	13.87	14.96	6.72	45.62	45.63
Panama	19.57	15.18	14.98	8.51	37.00	49.73

6.4 Twilight Measurements at Mauna Loa and Samoa

F. E. Volz

Air Force Geophysics Laboratory
Hanscom Air Force Base, MA 01731

For monitoring stratospheric aerosol by routine twilight radiance measurements, semiautomatic photometers were set up at MLO shortly before the Fuego volcanic eruption of December 1975, and at Samoa in June 1976. The effects of the Fuego dust cloud on twilights at MLO and at other locations (Volz, 1975, 1976) vanished by late 1976. Cloudless skies for twilight observations are quite frequent at MLO. Red/Green color ratios during 1977 suggest that background stratospheric aerosol concentration might have been slightly lower from mid-February to April and during August and September than during the rest of the year. Because of cloudiness, only a few useable twilight records similar to those at MLO have been obtained from Samoa.

6.5 Atmospheric Aerosol Measurements

Austin W. Hogan

State University of New York at Albany
Albany, NY 12222

The Atmospheric Sciences Research Center (ASRC) has frequently cooperated with the GMCC program, but has not previously contributed to the annual GMCC report. A review of significant results of previous programs is included as a preface to results obtained through the cooperation of the staff and the station personnel at the several GMCC stations in 1977.

6.5.1 South Pole Station

Cooperative GMCC-ASRC aerosol measurements began at South Pole Station in January 1974 and have continued to the present. The aerosol measuring instrument in use is a Pollak photoelectric nucleus counter (Pollak and Metnieks, 1960), which was constructed by R. Gussman and compared with the ASRC working standard (Gussman Pollak #12) before its shipment to Antarctica in November 1973. The ASRC working standard was compared with the Minnesota electrical analyzer and several other laboratory references close to the time it was compared with the South Pole instrument, facilitating direct comparison of South Pole aerosol measurements with tropical and mid-latitude measurements.

A Royco light-scattering aerosol detector has also been used to attempt to detect particles in the size range greater than 0.5 μm. The Rich (1966) diffuser-denuder technique, the Spurny et al. (1969) nuclepore technique, and the Sinclair (1972) diffusion technique have been used to estimate the size of the smaller (less than 0.5-μm diameter) particles.

The concentration of particles larger than 0.5-μm diameter is less than 1 particle per litre, and is difficult to measure with precision. Most of the particles have physical properties of spheres in the 0.1- to 0.2-μm diameter range, although many particles having physical properties equivalent to spheres of less than 0.02-μm diameter are found in dry subsiding air (Hogan, 1975).

The range of the total concentration of aerosol particles at the South Pole surface is extreme. Summer concentrations average about 100 particles cm^{-3}, but may range as high as 500 cm^{-3} with advection of "warm" moist air from the Weddell Sea (Hogan, 1977) and may exceed 1000 cm^{-3} in subsidence following frontal passage aloft. Maritime aerosols appear to constitute the majority of the total aerosol load. Winter concentrations rarely exceed 50 cm^{-3}, and may approach zero under strong near-surface inversions. A rapid rise in concentration accompanies astronomical sunrise. The variation in aerosol and surface ozone concentrations and in air temperature during a typical calendar year is shown in Fig. 62.

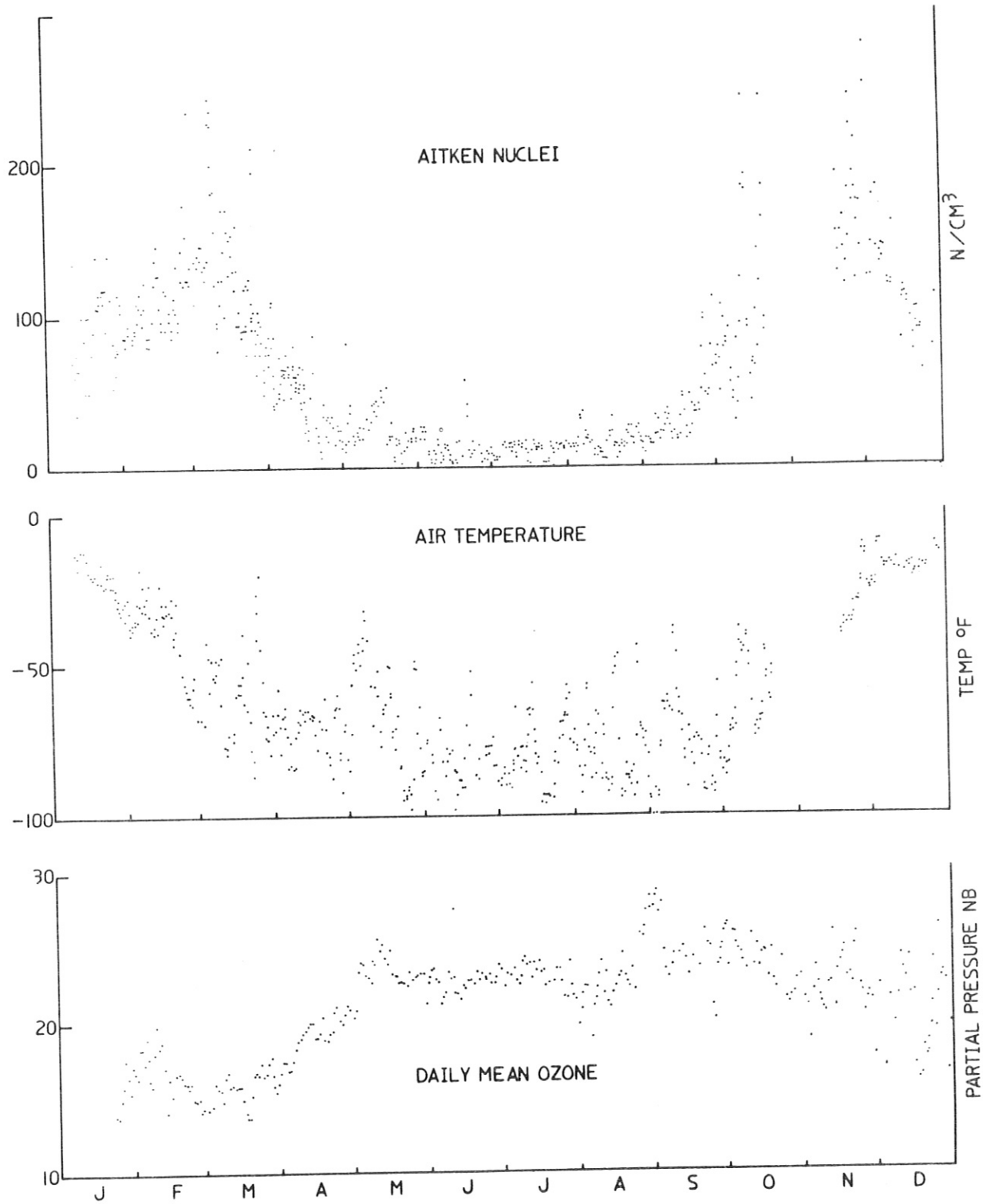


Figure 62. Variation in aerosol and surface ozone concentrations and air temperature at the South Pole, 1975.

6.5.2 Mauna Loa Observatory

GMCC-ASRC cooperation at MLO began in 1971, when Gussman Pollak 13 nucleus counter was installed in the observatory, in conjunction with Gussman Pollak 14 at the Woodcock Blanchard tower on the north shore of Oahu. Both of these instruments were compared with the ASRC working standard (Gussman Pollak 12) before transport to Hawaii. Gussman Pollak 14 was recently returned to Albany for recalibration, and although well corroded, it showed no change in sensitivity. A Rich diffuser-denuder was used for estimating particle size at Oahu, and a Royco light scattering device was used to detect particles >0.5 μm in diameter. A mean concentration of 242 cm^{-3} was found in trade winds in 1973, with most of the particulate material having physical properties similar to spheres >0.04-μm diameter, but less than 0.5-μm diameter. The concentration was found to be extremely variable with time, often ranging from 30 cm^{-3} to 300 cm^{-3} in a few hours. Flight experiments (Hogan, 1976) indicate that this variability is related to circulation through cumulus clouds. These flight experiments also indicated that measurements made at MLO during early morning downslope flow hours are representative of lower tropospheric air over much of the Pacific.

6.5.3 Point Barrow, Alaska

Field experiments were performed at and near the Barrow GMCC station during July and August 1977. Measurements were made by one observer at the GMCC site, using the GMCC Pollak counter, a Royco light-scattering detector, and a Sinclair 1972 diffusion battery, while the second observer made similar measurements at the sea shore, using a portable Royco and an HWG portable photoelectric nucleus counter (Hogan et al., 1975).

An extreme diurnal variation in aerosol concentration was found in onshore winds. Moderately low aerosol concentrations (100 to 500 cm^{-3}) were measured during morning fog. As the visibility improved, aerosol concentrations decreased; they approached zero (i.e., less than 15 cm^{-3}) on two occasions. Aerosol concentrations often rose rapidly into the 1,000-10,000 cm^{-3} range during sunny afternoons. These particles had the physical properties of spheres smaller than 0.02 μm in diameter, according to preliminary analysis of Sinclair size data. Interestingly, the concentration of small particles increased simultaneously at the observatory and at the shore. Since the initial hypothesis was that tundra plants might generate such aerosol through conversion of transpired vapors, these simultaneous measurements were repeated several times per day. Additional investigations, including discussions with officers of USCGC Glacier on August 2, indicated that the area upwind of the observation station was filled with pack ice, and that no ships had recently proceeded along the coast.

Preliminary analysis of radiosonde data (provided by the National Weather Service at Point Barrow) indicates that although the near-surface flow reaching Barrow is from seaward, flow only a few hundred meters above the surface is from the continent, i.e., the interior of Alaska. Air reaching the observatory on days when such extreme diurnal variations occur is apparently a mixture of polar maritime air of low aerosol concentration and continental air containing many "convertible" vapors. Particle formation can then greatly exceed coagulation in the air mass, and allow the existence of high concentrations of extremely small particles.

6.5.4 New Aerosol Instruments Applicable to GMCC Observation Program

Replicas of the HWG portable photoelectric nucleus counter (Hogan et al., 1975) have been in use at several GMCC stations for about 3 years. They are quite useful for quick-look data, where frequent readings of total aerosol concentration are required, and for field experiments that require aerosol measurement upwind or aloft of the station. An HWG was recently modified for rapid response and high sensitivity, for use in an Antarctic flight program. The light source was converted from a green to a red light-emitting diode (LED), allowing use of a faster photoresistor as a sensor. The lens arrangement is such that a narrow slightly converging light beam is projected along the axis of the fog tube. The sensitivity of the instrument used in Antarctica ranged from 0 to 3700 particles cm^{-3} between scale readings of 0 to 100. This instrument proved extremely useful in measuring nucleus concentrations over the Pacific and Antarctica during a recent research flight program.

A replica of a photographic Aitken counter (Winters et al., 1977) was recently completed for GMCC use. This instrument is sufficiently portable to be used in the field or at remote stations. Initial comparison experiments show no systematic difference between aerosol concentrations measured with this counter and with a Pollak counter. These and other comparison experiments indicate that modern aerosol observations, made with photoelectric counters, and historic measurements such as those made with Aitken and Scholz counters are directly comparable.

The instruments developed by Hogan et al. and Winters et al. were also recently used by Bigg and Vali in initial experiments at a baseline monitoring station in Tasmania.

6.6 Skylight Measurements at Mauna Loa Observatory

Kinsell L. Coulson

University of California
Davis, CA 95616

The research was directed toward developing a method of using the degree of polarization and intensity of the light from the sunlit sky as sensitive indicators of the amount of dust, haze, and other particulate matter in the atmosphere. Skylight measurements were made with a high-precision, computer-controlled polarimeter which was installed at an altitude of 3460 meters at the Mauna Loa Observatory. The measurements constitute the most extensive series of skylight measurements ever made at one location. The instrumentation operated well, and there was an unusually small amount of high cloudiness over Hawaii during the period. Reliable measurements were made on 63 days, for a total of over 350 hours of continuous measurements. More than a half million data points were obtained. Of more importance than gross numbers of points, however, is the fact that the data are believed to be consistent and sufficiently accurate for both characterizing atmospheric conditions at the time of the measurements and validating theoretical models of radiative transfer in a turbid medium.

Initial emphasis was obtaining the data, and only a cursory analysis has been possible so far. Study of the data and development of theoretical models for their physical explanation are anticipated. It has been possible, however, to plot a considerable number of polarization data, and to obtain a preliminary idea of the best index of atmospheric turbidity. Specifically, it is suggested that measurements of the degree of polarization in the direction of the zenith during a short period of time centered on sunrise may be used as a practical index of particulate loading of the atmosphere. Because of the effects of reflection of light from cloud tops at any other part of the sunlit period, measurements during the main part of the day would be less useful for the purpose. The necessary sunrise measurements could be made with a simple two-wavelength polarimeter which could be operated automatically by a computer at the observatory.

An example of results obtained from the measurements is given in Fig. 63, in which the degree of polarization of light from the zenith direction is plotted as a function of sun elevation for three successive days in April 1977. The dashed curve is the average for the ten clearest days on which measurements were taken; the solid curves are for measurements taken on the individual days. The meteorological conditions prevailing over the region of Hawaii during the period were characterized by strong cumulus activity, with cumulonimbus clouds extending to high levels in the atmosphere. The anomalously low values of polarization measured during the period are ascribed to the progressive build-

up of particulates and water vapor which were carried to the upper troposphere by vertical air movements in the cumulus clouds. Results are described in more detail by Coulson (1977, 1978).

A significant part of the success and a major share of the satisfaction I had in the measurement program were due to the excellent hospitality and cooperation of the Director, John Miller, and the staff of the Mauna Loa Observatory.

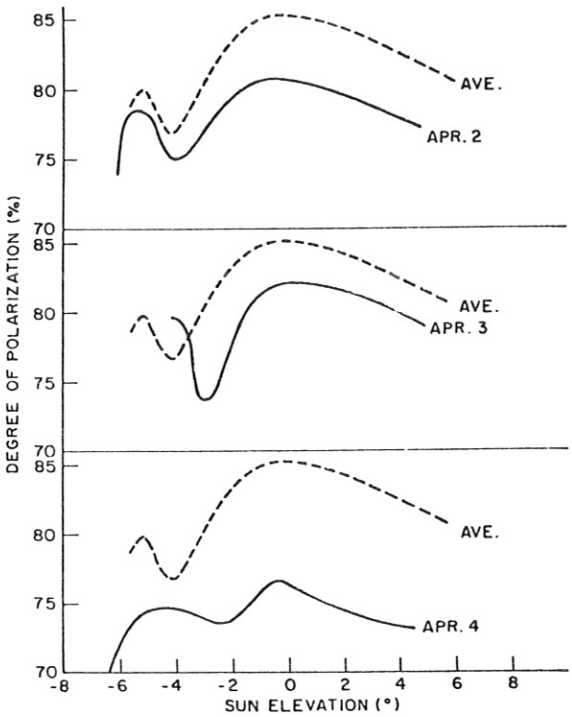


Figure 63. Degree of polarization at the zenith as a function of sun elevation as measured at a wavelength of 0.80 μ on days with moderate to high atmospheric turbidity (solid curves) compared with that for average low-turbidity conditions (dashed curves).

6.7 Trace Constituents of Aerosols at Samoa

Robert A. Duce

University of Rhode Island
Kingston, RI 02881

Investigators from the University of Rhode Island (URI), University of Connecticut (UCONN), and the California Institute of Technology (CIT) utilized the atmospheric sampling tower facility constructed by the University of Rhode Island on NOAA/GMCC station grounds at Cape Matatula, Samoa. Their work was part of an NSF-supported global study of the atmospheric sources, distribution, and fluxes of trace substances, particularly heavy metals, in marine aerosols. Unfortunately, the tower was destroyed by a hurricane in December 1976, but several investigations were carried out before the hurricane and on a partially rebuilt tower during 1977. The tower will be completely rebuilt in 1980.

Experiments on atmospheric lead were conducted by C. Patterson and co-workers from the California Institute of Technology from August 18 to 24, 1976, November 30 to December 6, 1976, and May 15 to 23, 1977. This work was part of a collaborative program sponsored by NSF with R. Duce and co-workers, URI, and with W. Fitzgerald and co-workers, UCONN. A manuscript describing this work is being prepared on wet and dry deposition fluxes of heavy metals in the southern Pacific.

The August 1976 experiment was a preliminary one to determine the amount of air required to pass through 0.02-μm and 0.4-μm Millipore filters to obtain reliable trace metal data. Twenty cubic meters were filtered, and preliminary results were obtained. The K/Ca ratio measured indicated that the bulk of solids on the filter was sea salts, and the lead concentration, although very low, was enriched with respect to crustal rocks. This enrichment was believed to be from anthropogenic lead contributions. These preliminary data revealed the necessity for collecting more solids on the filter if reliable measurements of metals were to be made. Procedures were modified and a second experiment was conducted in May 1977 using 0.4-μm filters (that were 90% efficient to 0.04 μm). At this time air was pumped through parallel filters at intervals over a period of 8 days. Air was pumped through the filters only when the wind was from offshore to avoid contamination from Pago Pago air. The pumps were also shut off when there was any precipitation. About 300 m^3 of air were pumped through the filters during a period of 8 days with about 4½ days of actual pumping.

During the period November 30, 1976, to December 6, 1976, rain samples were collected on the tower platform. Samples were obtained at the beginning of showers, at the end of showers, through entire showers, and when the wind direction was either from offshore or directly from Pago Pago. Rain samples were also collected for Duce and Fitzgerald,

and portions of the CIT samples were sent to Duce for Na and Al analyses so that the amount of silicate dust in the rain could be accurately determined. A portion of one sample was sent to K. Turekian, Yale University, for Pb^{210} measurement.

CIT determined concentrations of Pb, K, Rb, Cs, Ca, Sr, and Ba as well as Pb isotopic composition based on both bulk rain and filter samples for one unpolluted and one polluted rain event. A composite of Pago Pago gasoline was measured for Pb isotopic composition; it was the same as the polluted rain sample, showing graphically that Pb isotopic composition can be used to identify the source of anthropogenic Pb.

The concentration of Pb in Southern Hemisphere oceanic air was the lowest concentration measured to date anywhere in the world (0.1 ng Pb m^{-3}); however silicate aerosols in the air contain 100-fold more lead than natural dust or salt. Measurements of lead in rain at the NOAA/GMCC station allowed us to calculate the atmospheric input of soluble lead to the world oceans, $\sim 4 \times 10^4$ tons yr^{-1}.

Geochemical mass balance estimates by W. Fitzgerald for the global cycling of mercury indicated that the transfer of both naturally occurring and anthropogenic Hg species at the earth's surface is significantly affected by atmospheric transport and air/sea exchange. The data base for such estimates is quite limited. In particular, information about the geochemical behavior of Hg in remote marine environments is very sparse. During the week of October 3, 1977, W. Fitzgerald undertook a reconnaisance study to determine the range of Hg concentrations that can be expected in the near-surface, southeast trade winds at Tutuila Island, American Samoa. Atmospheric samples were collected for Hg determinations on the tower facility at the NOAA/GMCC station. The results, although preliminary, indicate the range of Hg concentrations in the southeast trades to be between 4 and 16 ng m^{-3}, virtually all in the gas phase. These measurements, which are unique, will be used in the experimental design of future mercury work.

Atmospheric samples collected during the sampling periods above (and during earlier, more extensive sampling periods in the spring and summer of 1976) were analyzed by the University of Rhode Island for a number of additional trace metals. The approximate concentrations observed for sodium, iron, zinc, arsenic, aluminum, and copper, as well as the CIT lead and UNCONN mercury values are presented in Table 24. With the exception of sodium, whose source is sea salt particles, the reported concentrations are the lowest ever recorded in the marine atmosphere.

Table 24. Approximate Atmospheric Metal Concentrations at American Samoa

Metal	Concentration (ng m^{-3} STP)	Metal	Concentration (ng m^{-3} STP)
Na	~2300	Zn	~0.4
Hg	~10	Cu	~0.2
Al	~1	Pb	~0.1
Fe	~1	As	~0.02

6.8 Aerosol Measurements at Point Barrow

Kenneth A. Rahn

University of Rhode Island
Kingston, RI 02881

Beginning in September 1976 and continuing through 1977 the University of Rhode Island's Atmospheric Chemistry Group has been taking continuous aerosol samples at Barrow. A high-volume system using Whatman No. 41 cellulose filters is operated continuously, subject to wind speed and direction controls. Filters are changed weekly to twice-weekly by NOAA personnel and mailed back to Rhode Island, where they are analyzed for trace elements by neutron activation. This research is part of a study of the Arctic aerosol sponsored by the Office of Naval Research (Contract N00014-76-C-0435, "Arctic Haze: Natural or Pollution?"). The results of this study, summarized below, have radically changed our understanding of the Arctic aerosol and its sources.

Although our analysis yields data on approximately 30 elements in the Barrow aerosol, certain of these are much more useful than others as indicators of specific sources. We have recently focused attention on the element vanadium (V), or more specifically its noncrustal or "excess" component, which seems to be a very specific indicator of combustion of residual oil in mid-latitudes. During the course of a year the concentration of excess, or pollution, V at Barrow varies greatly, with a winter maximum roughly 100 times greater than the summer concentration. The trace of excess vanadium for Barrow during 1976-77 is shown in Fig. 64, along with annual cycles for four other Arctic and mid-latitude sites for comparison. A number of features of this plot are worth noting.

First, the winter maximum at Barrow is much larger than in source regions such as New York or the northeastern United States in general, which have a winter maximum only a factor of 3 greater than the summer. This means that Barrow (and the Arctic in general) is much more cut off

from pollution sources in summer than in winter. We interpret this meteorologically in terms of seasonal migration of the jet stream/polar front system. In summer the system is located between mid-latitude pollution sources and the Arctic (and hence cuts off direct air flow between the two), but in winter it is over or south of the pollution sources (and hence allows the strong winter circulation to link sources and the Arctic). In summer, Barrow is essentially nonpolluted, but in winter it must be considered a polluted area. Although absolute concentrations of pollutants are low even in winter, the signature of pollution in the Barrow aerosol is unmistakable. Extremely interesting is the rapidity of change between summer and winter pollution regimes at Barrow. During both years in which we have been sampling at Barrow, the concentration of the pollution component of the aerosol increased suddenly in November or December and remained high for the rest of the winter. In each case the onset of this winter pollution regime occurred about two weeks after the jet stream/polar front moved (also suddenly) to the south.

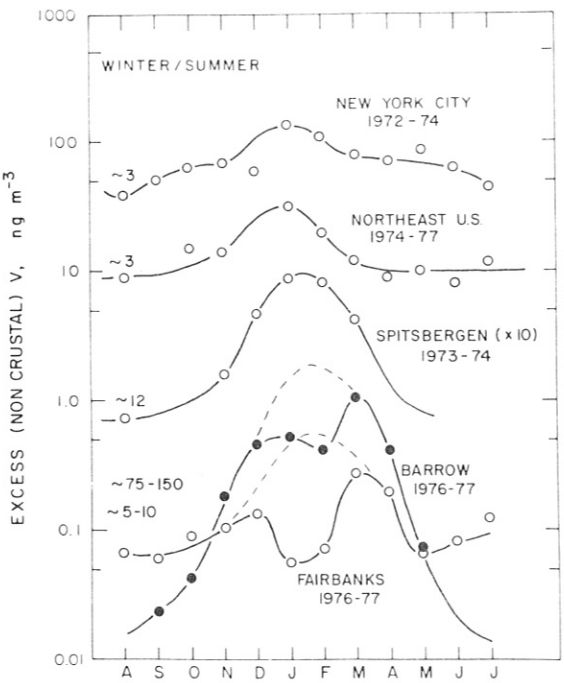


Figure 64. Monthly mean concentrations of excess vanadium (ng m^{-3}) near the surface of five mid-latitude and Arctic sites. The ratio of winter to summer concentrations is given on the left side.

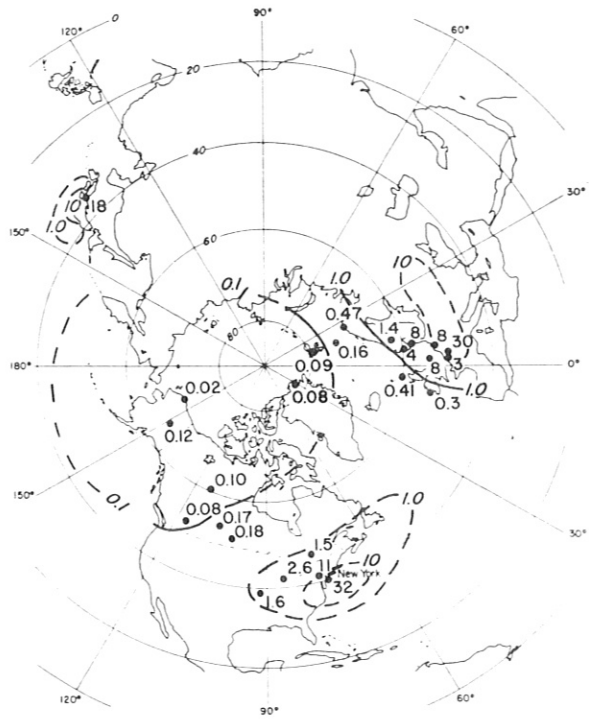


Figure 65. Concentrations of excess vanadium (ng m^{-3}) in the summer surface atmosphere of the Northern Hemisphere.

The second feature of interest from this plot is the double maximum in pollution vanadium observed at both Barrow and Fairbanks. This break in the winter maximum was a consequence of the unusual winter of 1976-77, during which there was abnormally strong and persistent flow of Pacific air northward over Alaska from December through February. This Pacific air is actually less polluted (at least during winter) than is Arctic air to the north (which has been more directly derived from pollution sources in North America and Europe), and so depresses the levels of excess vanadium throughout Alaska. At Fairbanks this depression started earlier and reached an earlier and lower minimum than it did in Barrow, because Fairbanks is 800 km south of Barrow, but the trends were qualitatively the same. Thus even the fine structure of pollution aerosol in Alaska can be explained in terms of large-scale sources and circulations.

The relation between Barrow and the rest of the Arctic during summer is quite different from the winter relation, and is shown in Fig. 65. Many of these data have come from preliminary measurements of the Arctic Air-Sampling Network, a cooperative undertaking now being organized between several countries. The plot shows a surprisingly regular picture of pollution in the Northern Hemisphere; the major source areas of Europe and the northeastern United States are seen clearly. Outside these areas the concentrations rapidly decrease to < 1 ng m^{-3}, and appear to have a "background" level of 0.1 ± 0.05 m^{-3}. Significantly, pollution vanadium is present at all Arctic sites even in summer, which should be the cleanest time of year. Note also the very low concentration at Barrow compared with the other sites. In fact, Barrow seems to be just about at the center of low concentrations, the "pole of minimum pollution." The displacement of this minimum well to the Alaskan/Siberian side of the geographical North Pole is due to the asymmetrical placement of strong pollution sources on the Greenland side of the Arctic, as well as the presence of major transport pathways from these sources to the Arctic.

During 1978 we will continue ground-level aerosol sampling in Barrow. Data for several years will be needed to establish the detailed relationships between sources, transport, and Arctic air quality. In addition, the important constituents lead and sulfate ion will be added to our elemental analyses. Results from this program have been reported by Rahn et al. (1977a, 1977b, 1978) and Rahn (1978).

6.9 Fluorocarbon Calibrations

R.A. Rasmussen

Oregon Graduate Center
Beaverton, OR 97005

In 1977 instruments for halocarbon measurements were intercalibrated twice between GMCC (T. Thompson) and OGC (R. Rasmussen). The first intercalibration was made with a blind sample sent to GMCC in Boulder as part of an exercise conducted with 16 laboratories (Rasmussen, 1978). Agreement between the submitted value of F-11, 150 ±1.6 pptv, and the value obtained by the GMCC laboratory of 145 ±0.5 pptv is very good. The GMCC value of 145 pptv is also close to the mean of the sixteen returned values, 140 ±16 pptv.

Thompson visited OGC in December and calibrated two of his long-term working standard reference gas tanks for N_2O, F-12, and F-11 concentrations. The concentrations assigned to the tanks before calibration were in close agreement with those obtained in the comparison with the calibration gases used at OGC. The concentration values assigned to the GMCC reference tanks are given in Table 25.

Table 25. Concentration Values Assigned to GMCC Reference Gas Tanks 3072 and 3078

	Tank 3072	Tank 3078
F-11	149.5 ± 2.3 ppt	355.8 ± 2.8 ppt
F-12	253.4 ± 1.7 ppt	285.7 ± 0.6 ppt
N_2O	331.4 ± 0.9 ppb	329.0 ± 2.1 ppb

6.10 Cloud Water Chemistry

Raymond E. Falconer

State University of New York at Albany
Albany, NY 12222

During the year a cloud water collector was built and installed at MLO with partial funding from GMCC (Fig. 66). The all-plastic parts are supported in the top of a wooden box in which the bottle collector or sampling block, plus a pH meter or other meters, can be mounted. The collector consists of two 2.5-cm-thick discs of polypropylene, one above the other, separated and supported by three 2.5-cm-diameter rods about 1 m long. Around the periphery of the two discs, nylon fishline (17.7 kg) is strung back and forth in grooves at a spacing of about every 3 mm. The bottom disc rests in the wide opening of a polypropylene funnel of 28-cm diameter. The collected cloud water runs down through the funnel and into a bottle. The whole assembly is mounted vertically. The collector is quite efficient as long as a wind is blowing; as much as 250 ℓ of cloud water have been collected in two hours on the summit of Whiteface Mt. The collector has withstood winds up to 65 mph, but does not withstand rime ice. Properly exposed it is omnidirectional. Because of a predominance of fair weather, few samples were obtained at MLO and results are not yet available.

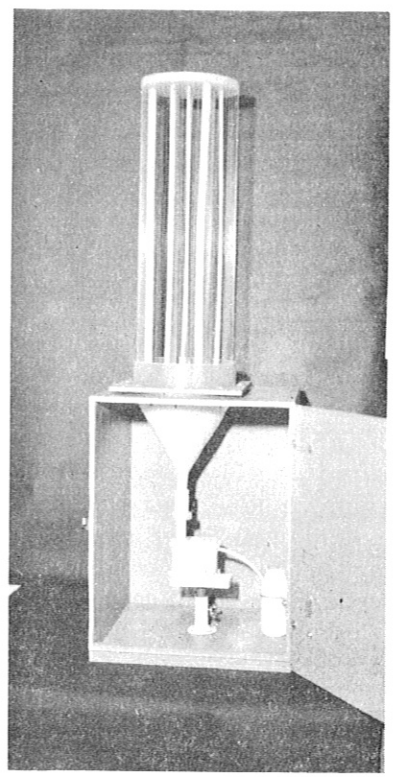


Figure 66. Cloud water collector installed at MLO.

Discussions between R. Falconer (ASRC) and J. Miller (GMCC) in 1975 led to establishment of the ASRC Whiteface Mt. Field Station in northeastern New York as one of four (now seven) rural precipitation chemistry stations in the MAP3S network. Collection of cloud water and measurement of its pH value began in the summer of 1976. Some of the most interesting measurements were taken between June 10 and July 1. For several hours before rain came the pH value of the cloud water was 3.9. In a separate simple rain collector (a large plastic funnel feeding rain through tubing into a plastic bottle) the rain had a pH value of 6.1 to 6.3, quite neutral. The cloud top was just above the 4867-ft summit of the mountain and the base was at 2,500 to 3,000 ft. Another rain collector at 2000 ft showed that, after the rain had fallen through the cloud, the pH was 4.1 to 4.2. This would seem to indicate that in the higher cloud, where the rain formed, there was little contamination. Falling through the cloud layer the raindrops scavenged out contamination on the cloud droplets, lowering the pH value.

In August and September 1977 cloud water pH was recorded during 328 and 496 hours, respectively, and rain was noted for 46 and 114 hours. There were substantially more hours of cloud water over Whiteface Mt. than of actual rainfall. The cloud pH values ranged from a low of 2.4 to a high of 5.4 in August and from 2.5 to 6.0 in September.

In mountain areas and locations where there is a predominance of fog or cloud water measurements of the pH, conductance, and other chemical content of cloud water should provide better insight into contamination in the lower atmosphere than can be obtained from precipitation alone. Contaminated cloud droplets bathe trees and other vegetation for many more hours than does falling precipitation. Thus, maintaining a monitor of fog or cloud pH should be as important as monitoring rain or snow alone.

6.11 Stratospheric Nitrogen Dioxide Measurements

Watson R. Henderson and John F. Noxon

Aeronomy Laboratory, NOAA
Boulder, CO 80302

A prototype spectrometer to monitor the stratospheric NO_2 column content with ground-based optical methods was installed at the GMCC Barrow Observatory in August 1975 and modified in November 1975. The instrument views out a window onto a mirror directed into the zenith sky and thus collects Rayleigh scattered sunlight. The data consist of sunlight intensity as a function of wavelength near 4450 nm, where NO_2 has several absorption features. The NO_2 concentration is sufficiently low that the absorption is small. However, since the amount of absorption increases when the light path passes obliquely through the atmosphere, data are normally taken during twilight. At these times, with enhancement factors of at least 10, the absorption can be as much

as a few percent. Twilight measurements have the additional advantage that the variation of absorption with zenith angle for angles greater than 90° can be interpreted to give a mean altitude of the NO_2 layer. This altitude is generally about 30 km with a variation of ±10 km. The intensity of scattered sunlight is too low for useful measurements of zenith angles greater than about 97°.

Data taken between November 1975 and January 1977 have been analysed and are shown in Fig. 67, where the twice monthly averages of the NO_2 column concentrations are plotted against the time of year. The principal features of interest are the factor-of-6 increases between winter and summer, and the sunrise-sunset asymmetry.

In early 1977 the original instrument at Barrow was replaced with a computer-controlled commercial spectrometer. Similar instruments were installed at Mauna Loa and Samoa. The instruments at Barrow and Mauna Loa were modified in early 1978 because the commercial spectrometers did not perform satisfactorily. Similar changes for the Samoa instrument are scheduled.

Interest in NO_2 in the atmosphere has increased for two reasons. First, the nitrogen oxides are the major natural constituent that catalytically destroys the ozone layer. Second, the odd nitrogen has a lifetime of many days so that, in principle, odd nitrogen can be used as a tracer for atmospheric circulation.

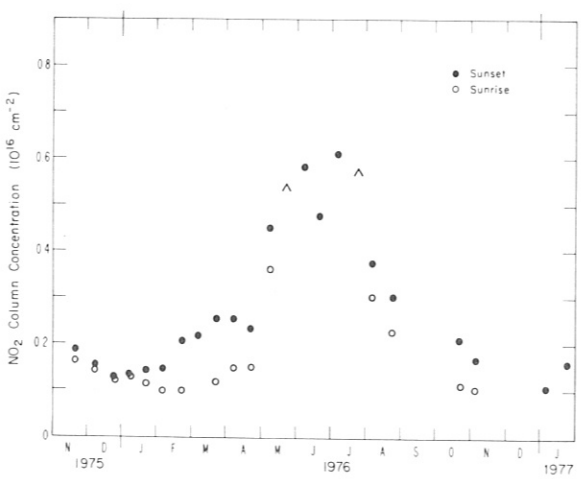


Figure 67. Twice-monthly averages of stratospheric column concentration of NO_2 obtained from Pt. Barrow, Alaska.

6.12 Precipitation Chemistry Measurements

Donald C. Bogen and Stuart J. Nagourney

Environmental Measurements Laboratory
U.S. Department of Energy, New York, NY 10014

The collection of wet, dry, and total deposition was initiated during the late spring of 1976 at American Samoa and at Mauna Loa Observatory. The samplers used for collection are described elsewhere (Volchok and Graveson, 1976; Galloway and Likens, 1976). Monthly samples are sent to the Environmental Measurements Laboratory (EML) for analysis.

At EML the volume, pH, and conductivity of the samples are determined. Chemical analyses are performed for the major anions and cations. Table 26 presents the average value and range of results obtained for the first twelve monthly samples collected at American Samoa. The primary cation and anion for these samples are sodium and chloride, respectively, suggesting sea spray as the principal constituent of the samples. The concentration ratios of the various cations and anions to chloride agree with published sea water ion ratios.

The ion balances (total cations/total anions) calculated for these samples (Table 26) indicate that the analytical results are satisfactory.

Table 26. Chemical Analyses of Total, Wet, and Dry Deposition, American Samoa, April 1976 through March 1977

	Total Collector		Wet Collector		Dry Collector	
	Mean	Range	Mean	Range	Mean	Range
Volume (liters)	5.4	0-12.2	7.7	1.8-13.6	- -	- -
pH	5.65	5.07-6.40	5.67	5.00-6.09	- -	- -
Conductivity ($\mu S\ cm^{-1}$)	88	34-124	28	13-50	- -	- -
Cl^- ($mg\ mon^{-1}$)	117	46-167	41	8-66	60	30-88
SO_4^{-2} "	18	8-30	8	3-15	8	4-12
NO_3^- "	0.5	ND-1.3	0.3	ND-0.6	0.3	ND-0.7
Na^+ "	60	26-104	22	6-44	27	16-45
Mg^{+2} "	6.9	2.9-12	2.7	0.8-5.0	3.2	1.9-5.4
Ca^{+2} "	3.8	1.9-6.0	1.6	0.6-2.9	1.4	0.9-2.4
K^+ "	3.0	0.9-5.5	1.3	0.3-2.2	1.2	0.3-1.8
Total Cations/Total Anions	0.96 ± 0.12		1.0 ± 0.18		0.90 ± 0.08	

μS = micro-siemen
ND = not detectable

Table 27 presents the means and ranges of results obtained for the first six monthly samples collected at Mauna Loa. The major anion was sulfate. Equal concentrations of sodium and calcium were observed, suggesting other sources besides the marine aerosol.

Table 27. Chemical Analyses of Total, Wet, and Dry Deposition at Mauna Loa, April 1976 through September 1977

	Total Collector		Wet Collector		Dry Collector	
	Mean	Range	Mean	Range	Mean	Range
Volume (liters)	1.3	0-2.6	1.19	0-5.3	- -	- -
pH	5.29	4.91-5.67	5.85	4.76-6.66	- -	- -
Conductivity ($\mu S\ cm^{-1}$)	15.2	7.0-23.4	6.6	1.8-15.5	- -	- -
Cl^- ($mg\ mon^{-1}$)	0.15	0.09-0.21	0.14	ND-0.27	0.16	0.04-0.34
SO_4^{-2} "	0.78	ND-2.0	0.81	0.01-2.25	0.38	0.09-0.92
NO_3^- "	0.13	0.04-0.19	0.23	ND-0.49	0.18	0.04-0.42
Na^+ "	0.13	0.02-0.26	0.19	ND-0.77	0.10	0.02-0.22
Mg^{+2} "	0.025	ND-0.052	0.025	ND-0.076	0.020	ND-0.062
Ca^{+2} "	0.12	ND-0.47	0.10	ND-0.27	0.10	ND-0.27
K^+ "	0.043	0.015-0.10	0.076	ND-0.41	0.046	0.010-0.18

ND = not detectable

6.13 Nuclear Fallout and High Volume Aerosol Collections

Herbert W. Feely

Environmental Measurements Laboratory
U. S. Department of Energy, New York, NY 10014

Precipitation samples, which are analyzed for ^{90}Sr fallout from atmospheric tests of nuclear weapons, are collected in plastic buckets at the Mauna Loa and Samoa observatories on a monthly basis. They are currently combined into quarterly composites and are analyzed together with samples from about 70 stations in other parts of the world. An interpretation of recent results has been given by Feely et al. (1978).

High volume filter samplers, which sample air at about 1 m^3 min^{-1}, are operated for EML at all four GMCC observatories. These are part of a network of about 22 filter samplers operated for EML, mainly in the Western Hemisphere. Monthly composites of the filter samples are analyzed routinely by gamma spectrometry for ^{7}Be, ^{95}Zr, ^{137}Cs, and ^{144}Ce. Until mid-1976 they were also routinely analyzed radiochemically for ^{210}Pb, ^{90}Sr, and $^{239,240}Pu$, and by atomic absorption spectrometry for elemental Pb. A program to analyse the filters for several trace metals by means of X-ray fluorescence has begun, starting with samples collected during late 1975. Results are reported quarterly.

During the spring of 1976, a system that used wind direction to determine which of two filter samplers would be operating was installed at Mauna Loa in an effort to sample the air separately under upslope and downslope wind conditions. It was plagued with repeated equipment failures, and a clock-controlled system for operating the two samplers is currently in use while a new wind-direction system is being tested at EML.

Table 28 summarizes quarterly mean concentrations of the various radionuclides measured in surface air filters from 1975 to 1977. The cosmic-ray product, ^{7}Be, is high in concentration at the Mauna Loa Observatory throughout the year. This station appears to represent better the air of the upper troposphere than does the EML continental station at Chacaltaya, Bolivia, even though the latter, at 5220 m, is located at a higher altitude. Concentrations of ^{7}Be at the South Pole Observatory show a summer maximum and a winter minimum. Evidently, air from the high troposphere carrying ^{7}Be takes longer to reach the surface layer during winter than it does during summer. This argues against a conclusion, based on observations of the seasonal variations in concentrations or surface level ozone at the South Pole, that attributes high wintertime ozone concentrations to rapid movement of air to the surface from the polar stratosphere or upper troposphere.

Table 28. Quarterly Mean Concentrations of Radionuclides in Surface Air Filter Samples Collected at GMCC Observatories, 1975 to 1977

	1975				1976				1977	
	1	2	3	4	1	2	3	4	1	2
^{7}Be (fCi m^{-3})										
Barrow Obs.	-	-	-	53	84	48	21	65	85	65
Mauna Loa Obs.	205	260	256	220	227	-	-	-	249	-
Matatula Obs.	-	-	-	-	-	44	96	73	57	78
South Pole Obs.	154	94	108	161	156	48	68	136	-	-
^{90}Sr (fCi m^{-3})										
Barrow	-	-	-	0.10	0.22	0.13	0.04	-	-	-
Mauna Loa Obs.	1.63	2.25	0.60	0.18	0.43	-	-	-	-	-
Matatula Obs.	-	-	-	-	-	0.01	0.09	-	-	-
South Pole Obs.	0.61	0.44	0.29	0.30	-	-	-	-	-	-
^{95}Zr (fCi m^{-3})										
Barrow Obs.	-	-	-	$\leq$0.1	0.2	$\leq$0.1	$\leq$0.1	4.4	1.2	5.8
Mauna Loa Obs.	22.2	7.7	0.6	0.2	$\leq$0.2	-	-	-	45.6	-
Matatula Obs.	-	-	-	-	-	$\leq$0.1	$\leq$0.1	$\leq$0.1	$\leq$0.1	$\leq$0.1
South Pole Obs.	10.9	4.1	1.2	0.3	$\leq$0.1	$\leq$0.1	$\leq$0.1	$\leq$0.1	-	-
^{137}Cs (fCi m^{-3})										
Barrow Obs.	-	-	-	0.27	0.35	0.30	0.06	0.21	0.27	0.44
Mauna Loa Obs.	2.99	3.12	0.81	0.48	0.77	-	-	-	1.56	-
Matatula Obs.	-	-	-	-	-	0.10	0.16	0.13	0.09	0.06
South Pole Obs.	0.86	0.57	0.36	0.50	0.39	0.18	0.13	0.16	-	-
^{144}Ce (fCi m^{-3})										
Barrow Obs.	-	-	-	0.6	1.0	0.4	$\leq$0.2	1.2	0.5	4.6
Mauna Loa Obs.	34.1	25.6	4.6	1.2	2.2	-	-	-	20.5	-
Matatula Obs.	-	-	-	-	-	0.2	0.2	0.2	$\leq$0.2	$\leq$0.2
South Pole Obs.	7.6	5.7	3.1	2.2	0.7	$\leq$0.2	0.2	0.2	-	-
^{210}Pb (fCi m^{-3})										
Barrow Obs	-	-	-	23.7	26.3	7.8	1.7	-	-	-
Mauna Loa Obs.	8.5	14.8	9.8	6.3	8.4	-	-	-	-	-
Matatula Obs.	-	-	-	-	-	0.4	0.8	-	-	-
South Pole Obs.	1.1	0.5	0.7	1.1	-	-	-	-	-	-
^{239}Pu (aCi m^{-3})										
Barrow Obs	-	-	-	2.4	5.5	3.2	5.4	-	-	-
Mauna Loa Obs.	42.4	43.2	12.4	3.1	9.5	-	-	-	-	-
Matatula Obs.	-	-	-	-	-	$\leq$1.0	2.7	-	-	-
South Pole Obs.	11.3	7.3	3.3	5.2	-	-	-	-	-	-

The artificial radionuclides from nuclear weapons tests have been measured in the filters. These include $^{239,240}Pu$ and the fission products ^{90}Sr, ^{95}Zr, ^{137}Cs and ^{144}Ce. At the South Pole Observatory these artificial radionuclides were high in concentration during early 1974 as a result of June-September 1974 weapons tests by the French. The concentrations of artificial radionuclides were high at Mauna Loa Observatory during early 1975 as a result of a June 1974 Chinese weapons test, and at both Mauna Loa and Barrow Observatories during late 1976 and early 1977 as a result of the September and November 1976 Chinese tests.

6.14 Precipitation Chemistry on Hawaii

James N. Galloway

University of Virginia
Charlottesville, VA 22903

For a four-week period in July 1977, a ten-station precipitation chemistry network was in operation on the Island of Hawaii. Precipitation was collected on an event (storm by storm) basis in bulk (wet and dry deposition) precipitation collectors. The sampling sites were on an altitudinal gradient between Hilo (sea level) and Mauna Loa Observatory (11,000 ft). The samples were analyzed for pH, SO_4, NO_3, Cl, NH_4, Ca, Mg, Na, K, total acidity, and strong acidity. Examples of the differences in precipitation composition as a function of altitude are presented in Figs. 68 and 69. It is clear that there are large concentration gradients in precipitation that are dependent on altitude.

At the Mauna Loa Observatory, precipitation pH can be as low as 4.5. Experiments were performed to determine if the low pH (high acidity) was due to strong or weak acids and what the acids were. From determination of total composition, total acidity, and strong acidity it was concluded that the acid precipitation at Mauna Loa is due to sulfuric acid. The two sources for this acid are transport from Hilo and contamination of precipitation by SO_2 from volcanic activity.

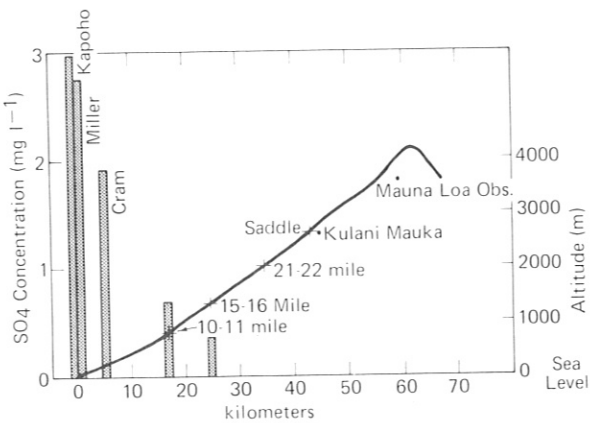


Figure 68. Weighted average sulfate values for the 4-week collection period at sampling sites between the sea coast (Hilo) and MLO.

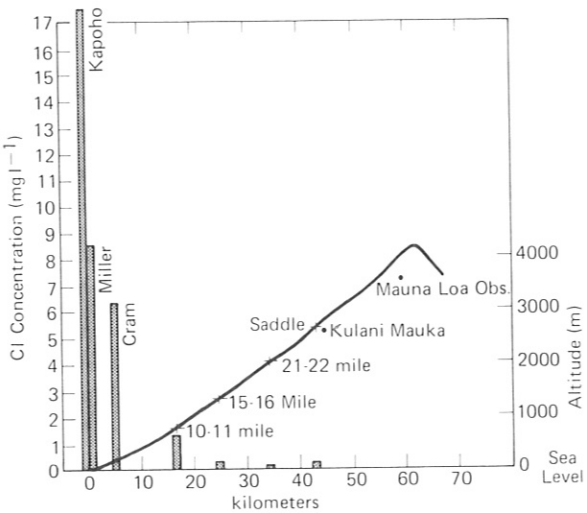


Figure 69. Weighted average chloride values for the 4-week collection period at sampling sites between the sea coast (Hilo) and MLO.

7. GRANTS AND CONTRACTS

7.1 Contribution of Broad-Band Pyrheliometric Measurements to Solar Constant Monitoring

G. D. Robinson

Center for the Environment and Man
Hartford, CT 06120

The contract's object is to examine records of the broad-band channels of the multichannel pyrheliometer at Mauna Loa Observatory and to assess the potential of this type of instrument as a precision monitoring device. The method adopted is an extension of the "Langley plot" technique to broad spectral bands; the quantity plotted is not the measured irradiance but the difference between the measured irradiance and that computed under certain assumptions. These assumptions concern the 'solar constant', the solar spectral irradiance outside the atmosphere, and the composition of the atmosphere. As far as the solar constant is concerned, the requirement is for a value consistent with the calibration of the MLO equipment rather than for an absolute standard, and it is considered that reference to the Eppley Laboratory standards assures this to the degree possible at this date. In previous work, the Labs-Neckel specification of the solar spectrum has been shown to be more consistent with the MLO observations than the Thekaekera spectrum; this is consistent with the findings of other workers and with the current consensus.

The method used calls for knowledge of the water content and ozone content of the atmosphere, but considerable progress can be made with approximate measurements or estimates because the H_2O absorption is substantially confined to the pass band of the RG8 filter and the short-term variations of O_3 content above MLO have relatively little absolute effect on the Chappuis band extinction which affects mainly the difference between the OG1 and RG8 channels. The usefulness of the method depends to a considerable extent on redundancy in the measurements. For example, the infrared component isolated by RG8 is measured by all filters, and systematic differencing of the channels can give considerable insight into the nature of systematic errors. Figure 70 illustrates some aspects of the method. It plots computed irradiance minus measured irradiance for the quartz and RG8 channels and for the difference combinations against air mass. The plot is linear; the residual extinctions are small. The slopes of the lines (to first order) give information concerning the atmosphere. The intercepts on the zero air-mass axis give information concerning the assumptions, including the calibration factors of the thermopiles (which have a second-order effect on the slopes), the cut-off of the filters, and the extraterrestrial spectrum. For example, the point marked with an arrow is affected by a temporary increase in water content of the atmospheric path. (It is not anomalous on the differential channels.) Other deductions that can be made include a

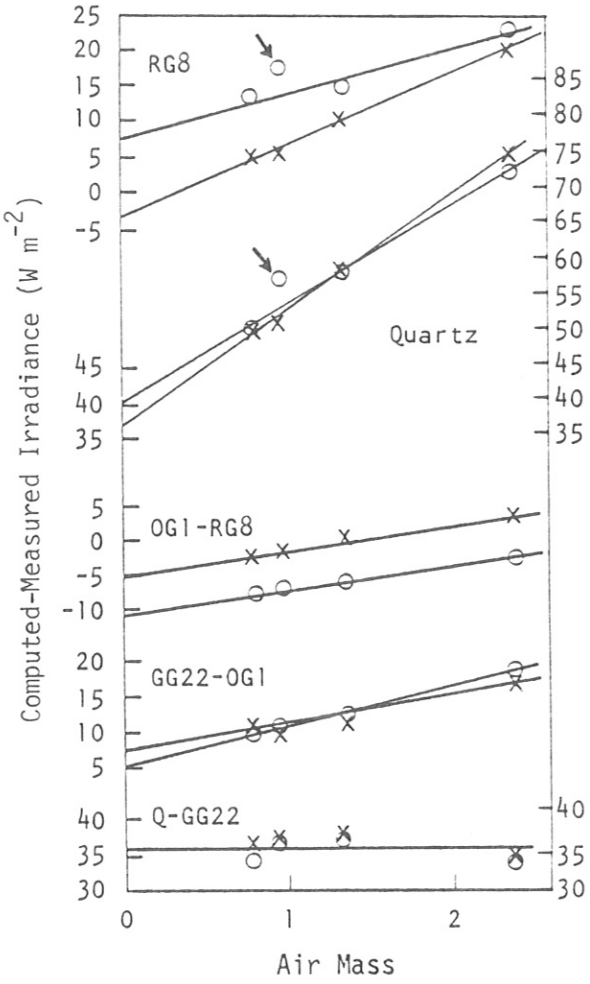


Figure 70. Computed minus measured irradiance for several spectral intervals of the direct solar beam at MLO on August 23 (x) and 24 (o), 1978.

change in overall sensitivity of the RG8 channel between the two days, a slight change in sensitivity of the GG22 channel (the major evidence of this is not plotted in Fig. 70), and a major uncertainty concerning the quartz channel (almost certainly due to an incorrect applied sensitivity) and possibly also an incorrect assumption concerning the infrared cutoff. With the application of indicated corrections, the residual extinction of the atmosphere was 0.011 per air mass in the OG1/RG8 channels and 0.02 ± 0.004 in the GG22/OG1 channel on 23/24 August 1975.

The major difficulty in this investigation has been loss of record caused by mechanical failure of the heliostat, which is not always obvious without analysis. The results suggest that, with attention to detail and analysis for systematic error, the multichannel broadband pyrheliometer is capable of a precision of 0.2% in the visible range of the spectrum. With this performance, it becomes a useful adjunct both to the much more elaborate spectroradiometers required for systematic solar constant monitoring and to the scattering based techniques most suitable for monitoring the atmospheric particle load.

7.2 Site Evaluation for Geophysical Monitoring for Climate Change-II

Elmer Robinson

Washington State University
Pullman, WA 99163

The second phase of research by Washington State University (WSU) on a possible midlatitude, west coast site for a GMCC station was carried out from February 1976 to February 1977. A final report was prepared by Shives and Robinson (1977). Previous research had used the general climatological data of the area to assess the changing climatological conditions from north to south along the coast. Part of the second phase consisted of field measurements to assess two coastal sites--Cape Blanco, Oregon, and Point Grenville, Washington. The measurement program was conducted during the summer of 1976 to determine the more suitable location for a permanent facility to monitor background levels of certain trace atmospheric constituents. The permanent facility would be a part of the GMCC/NOAA program and the World Meteorological Organization.

A previous study by WSU of the climatology and coastal circulation patterns had indicated a greater frequency of occurrence of air of marine trajectory for the northern half of the region. More frequent alongshore flow with possible resulting contamination from coastal and inland sites was predicted for the southern section. Major objectives of the second phase of the research were to determine whether locations of the southern Oregon coast were affected by anthropogenic emissions during prevailing summertime northerly wind situations and to compare conditions there with conditions on the central Washington coast.

The research data gathered during the program show rather conclusively that the prevailing northerly summer winds at Cape Blanco do have higher concentrations of CN and biased CO_2 concentrations, both of which are indicative of recent anthropogenic or land-based biogenic influences on the air parcels passing over the Cape. On the other hand, at Point Grenville on the central Washington coast the prevailing summer wind was from the northwest, an oceanic trajectory with little or no recent land exposure. This resulted in Point Grenville having lower CN concentrations than Cape Blanco. However, even at Point Grenville the average CN concentrations from the clean air sector were about 1100 n cm^{-3} or more than twice the 500 n cm^{-3} that is frequently considered indicative of the open ocean marine atmosphere. It was not possible to identify the source of these CN concentrations, although it is believed that they are natural constituents of the atmosphere rather than anthropogenic.

The CO_2 data from both locations apparently suffered from local biogenic influences since all the data tabulations exhibited a diurnal cycle. This cycle was characterized by higher CO_2 levels in the early

morning when biogenic CO_2 emissions commonly occur and lower CO_2 concentrations in the mid-afternoon when the biosphere is in a CO_2 uptake phase.

When only air from the clean air sector at each station was considered, the diurnal cycles were reduced but they were still quite apparent. This was attributed to local biospheric influences since it was not possible to avoid a fetch across vegetation areas in establishing sampling sites for this temporary program. At both locations, when the winds had a good oceanic fetch, CO_2 concentrations approached present global CO_2 levels, and CN concentrations were not indicative of anthropogenic influences. Thus, it seems that both sites could provide valid background CO_2 data and that at Point Grenville the frequency of suitable background conditions would be much greater than at Cape Blanco. At Grenville the prevailing summer synoptic situations favor a clean air fetch at the station. This is not the case at Cape Blanco where the prevailing summer flow is influenced by anthropogenic and other land area activities.

If additional site location studies are carried out, they should probably be concentrated in the Point Grenville area of Washington.

7.3 Multi-Wavelength Turbidity at the Mauna Loa Observatory

Glenn E. Shaw

Geophysical Institute, University of Alaska
Fairbanks, AK 99701

This report describes results of a study to measure multi-wavelength optical transmission through the atmosphere above Mauna Loa, its variation with time, and its relation to geophysical parameters.

The vertical optical thickness from scattering and absorption of light by aerosols at MLO averages 0.020 at wavelength 500 nm, and 0.004 at 1000 nm, but varies from day to day by ±25%. Air that has come from easterly and northerly directions is slightly more turbid ($\delta\tau \simeq 0.01$) than air from southwesterly directions; the increase in turbidity is probably due to continental aerosols from America reaching the islands. The optical extinction of the continental aerosol varies with wavelength as λ^{-2}. During clearest conditions at MLO, the aerosol optical thickness at 500 nm was only 0.010 to 0.015.

Almost all the reported turbidity measurements were made in the morning during subsidence conditions and are thought to be representative of "background" turbidities in the central Pacific. In the afternoon, the marine trade inversion breaks up, and turbidity increases and fluctuates because of contamination aerosol brought to the observatory altitude by anabatic winds and convection.

There was a slow decay in day-averaged aerosol extinction from March to June 1976 that has been identified with the dust veil caused from the explosive eruptions of Augustine volcano in the Gulf of Alaska in January-February 1976; a Dust Veil Index of 4 has been assigned to the Augustine eruption on the basis of the optical measurements made at MLO. This compares with DVI = 1000 for Krakatoa (1883), DVI = 150 for Katmai (1912) and DVI = 800 for Agung (1963). The aerosol extinction spectrum for the Augustine dust veil is approximately given by $\tau = 0.0125\ \lambda^{-1}$, and an inversion, according to the method of Box and Lo, indicates that the total mass of material in the stratosphere (March 1970) was 10^{12}g.

Some preliminary extraterrestrial solar irradiance measurements were made during this study at twelve 10-nm-wide wavelength regions by using the Langley method to extrapolate through the atmosphere and an NBS primary standard tungsten lamp to refer the measurements of spectral intensity to SI electrical units. A check on the absolute accuracy of the lamp calibration was made (at one wavelength : 615.9 nm) by using a tunable dye laser and electrically-calibrated cavity radiometer at the World Radiation Center at Davos, Switzerland. The determinations of spectral intensity agree to within ±5% of those reported by Labs and Neckel. Error analysis of derived data shows that the extrapolation through the atmosphere introduces less than 0.5% uncertainty into the determinations of solar spectral irradiance.

The solar spectral irradiance from March to August 1976 remained constant to better than 0.3% at yellow to red wavelengths, but there were indications that the sun may have brightened slightly over 5 months' time by about 0.4% to 0.8% at blue (400 nm) wavelengths.

Atmospheric ozone and water vapor amounts were obtained at MLO by measuring optical absorption in the Chappuis band and in the ρ-σ-τ water band. Ozone amounts derived from Chappuis-band absorption were 23% lower than those derived with a Dobson spectrophotometer but correlated to within ±4% with the Dobson values. Column water vapor increased through the day; the morning values ranged from 0.5 to about 2.5 g cm^{-2}, although these values are somewhat uncertain because of poor information available on spectroscopic line parameters in the near infrared region. Evidence was found for a weak water vapor continuum between the ρ-σ-τ and ϕ band with an absorption coefficient ~ 0.08 $g^{-1}cm^2$.

Results of this study show that precision multi-wavelength spectrophotometry can be used to quantify and monitor important geophysical parameters that have bearing on climate.

8. INTERNATIONAL ACTIVITIES

J. Miller participated in a consultants' meeting for the coordination of WMO Background Air Pollution Monitoring and International Atomic Energy Agency (IAEA)/WMO Isotopes in Precipitation networks at the IAEA Headquarters, Vienna, Austria, October 4 to 6, 1977.

S. Oltmans and M. Johnson traveled to the South Pole on January 3, 1977, via New Zealand and McMurdo, Antarctica. Their purpose was to transfer GMCC program equipment from the temporary, undersnow facility to the newly constructed Clean Air Facility. With the help of GMCC winter-over personnel B. Halter and G. Rosenberger, equipment and supplies were transferred smoothly and most equipment was soon back in operation. In addition, gas and aerosol sampling stacks were installed, a meteorology mast was erected, a platform for the solar radiation sensors was constructed and installed, equipment was rehabilitated, and special calibrations were carried out. On his return Johnson stopped in Samoa for equipment maintenance and erection of a sampling stack tower.

B. Bodhaine traveled to Galway, Ireland, September 21 to 27, 1977, to attend the Ninth International Conference on Atmospheric Aerosols, Condensation and Ice Nuclei. The conference, held at University College, was sponsored primarily by the International Association of Meteorology and Atmospheric Physics. Bodhaine's paper (Bodhaine, 1977) described one of the few programs for long-term monitoring of background conditions.

GMCC took an active role in the international intercomparisons and maintenance of Dobson spectrophotometers for total ozone measurements. R. Grass traveled to South America in early 1977 to calibrate and maintain four instruments in Peru, Argentina, and Brazil. In October and November, he checked instruments in Iceland, Denmark, Norway, and Spain. During July and August 1977 GMCC was host to an international intercomparison of Dobson spectrophotometers, in which eight countries participated under WMO sponsorship. GMCC Dobson No. 83 has been designated by WMO as the World Primary Standard for total ozone measurements. Details of the intercomparisons are given in section 3.2.

W. Komhyr traveled to Leningrad, USSR, in August under the US-USSR bilateral agreement on climatic change, Working Group VIII. He brought an ECC ozone meter to the USSR and trained Soviet specialists in its use. He also discussed possible cooperation on CO_2 monitoring. The Soviets use a spectrophotometric technique to measure the total atmospheric column amount of CO_2 whereas we use non-dispersive infrared techniques to obtain (local) ambient concentrations.

B. Mendonca served as an advisor to the National Meteorological Department of Brazil. He was in Brasilia from November 8, 1977, to

December 16, 1977, to help establish a national solar radiation calibration center. The Organization of American States sponsored the trip. The main objectives of Mendonca's consultation were to review all solar equipment, including an integrating calibration sphere, to decide on the permanent location and layout of the radiometric instruments at the national calibration center, and to install the instruments on a temporary platform for field checking and training of technicians.

On November 3 and 4, 1977, K. Hanson visited Leningrad, USSR, under the auspices of the US-USSR bilateral scientific exchange agreement on climate change--Working Group VIII. Four topics were covered: (1) a possible US-USSR program of air-flask sampling with particular emphasis on establishing sampling for CO_2 at ocean station "C" in the North Atlantic, now occupied by the USSR; (2) discussions with Professor Kondratyev concerning present GAAREX activities in the USSR and possible collaborative efforts of the US-USSR on GAAREX type experiments under the bilateral agreement; (3) a US-USSR intercomparison of Dobson spectrophotometers; (4) a continuation of the discussions initiated by W. Komhyr on a possible US-USSR cooperative program in atmospheric CO_2 monitoring and exchange of instruments.

After his Leningrad visit, K. Hanson attended a UNEP/WMO- sponsored meeting of "Selected Experts on Climate-Related Monitoring" at Geneva, Switzerland. The purpose of the meeting was to prepare an outline for a background paper on the needs for climate-related monitoring. Authors were selected for various sections of the paper, which is intended to serve as a background document for a "Government-Expert Meeting on Climate-Related Monitoring" scheduled for mid-1978.

9. PUBLICATIONS AND PRESENTATIONS BY GMCC STAFF

Bergstrom, R. W., and J. T. Peterson (1977): Comparison of observed and predicted solar radiation in an urban area. J. Appl. Meteorol., 16(10):1107-1116.

Bodhaine, B. A. (1977): Nuclei monitoring at baseline sites: Barrow, Alaska, Mauna Loa, Hawaii, American Samoa, and South Pole, Antarctica. Presented at 9th Inter. Conf. on Atmospheric Aerosols, Condensation and Ice Nuclei, Galway, Ireland, September 1977.

Cram, R. S., and K. J. Hanson (1977): The United States B-scale surface radiation subprogram of GATE: Instrumentation and data validation. NOAA Tech. Memo. ERL-ARL-65, Boulder, Colo., 88 p.

DeLuisi, J. J., and B. M. Herman (1977): Estimation of solar radiation absorption by volcanic stratospheric aerosols from Agung using surface-based observations. J. Geophys. Res., 82:3477-3480.

DeLuisi, J. J., and B. M. Herman (1977): Radiative properties of stratospheric aerosols from Agung. Proc. Symp. on Radiation in the Atmosphere, Garmisch-Partenkirchen, FRG, August 1976, H.-J. Bolle, ed., Science Press, 123-125.

Deluisi, J. J., J. E. Bonelli, and C. E. Sheldon (1977): Spectral absorption of solar radiation by the Denver brown (pollution) cloud. Atmos. Environ., 11:829-836.

Fegley, R. W. (1977): The NOAA stratospheric lidar project--recent results. Presented at 8th Inter. Conf. on Laser Atmos. Studies, Philadelphia, Pa., Amer. Meteorol. Soc.

Hanson, K. J. (ed.), (1977): Geophysical Monitoring for Climatic Change No. 5, Summary Report 1976. ERL/NOAA, Boulder, Colo., 110 p.

Hanson, K. J. (ed.), (1977): Project Development Plan: A plan for surface-based monitoring of climatically important variables, vols. I and II. Air Resources Laboratories, NOAA, Boulder, Colo.

Hoyt, D. V. (1977): A redetermination of the Rayleigh optical depth and its application to selected solar radiation problems. J. Appl. Meteorol., 16:432-436.

Hoyt, D. V. (1977): Percent of possible sunshine and the total cloud cover. Mon. Wea. Rev., 105:648-652.

Hoyt, D. V. (1977): Comments on climate change: an appraisal of atmospheric feedback mechanisms employing zonal climatology. J. Atmos. Sci., 34:1824-1825.

Komhyr, W. D. (1977): Ground-based total ozone measurements. Position Paper, prepared for the National Aeronautics and Space Administration, Greenbelt, Md.

Komhyr, W. D., and T. B. Harris (1977): Measurements of atmospheric CO_2 at the U.S. GMCC baseline stations. In Air Pollution Measurement Techniques, WMO Special Environment Rep. No. 10, Rep. and Proc. of WMO Air Pollution Measurement Techniques Conf. (APOMET), Gothenburg, Sweden, October 1976, WMO Rep. No. 460, 9-19.

Komhyr, W. D., and T. M. Thompson (1977): Fluorocarbon-11 measurements at the U.S. GMCC baseline stations. In Air Pollution Measurement Techniques, WMO Special Environment Rep. No. 10, Rep. and Proc. of WMO Air Pollution Measurement Techniques Conf. (APOMET), Gothenburg, Sweden, October 1976, WMO Rep. No. 460, 208-215.

Machta, L., G. Cotton, W. Hass, and W. D. Komhyr (1977): CIAP measurements of erythemal solar ultraviolet radiation. Proc. Joint Symposium on Atmospheric Ozone, Dresden, GDR. K. H. Grasnick, ed., vol. III, GDR Acad. Sci., Berlin, 87-104.

Miller, J. M. (1977): Precipitation chemistry measurements at baseline observatories. Presented at AGU Spring Meeting, Washington, D.C., May 30-June 3.

Peterson, J. T. (1977): Dependence of the NO_2 photodissociation rate constant on altitude. Atmos. Environ., 11(8):689-695.

Peterson, J. T. (1977): Statistical editing of background carbon dioxide measurements. Preprints, 5th Conf. on Probability and Statistics in Atmos. Sci., Las Vegas, Nevada, Amer. Meteorol. Soc., 158-161.

Peterson, J. T., W. D. Komhyr, T. B. Harris, and J. F. S. Chin (1977): NOAA carbon dioxide measurements at Mauna Loa Observatory, 1974-1976. Geophys. Res. Letters 4(9):354-356.

Peterson, J. T., and V. Szwarc (1977): Geophysical monitoring for climatic change at the South Pole. Antarctic J. of the United States, 12(4):159-160.

10. REFERENCES

Air Resources Laboratories (1978): Monitoring the solar constant and solar ultraviolet, a report and recommendations from a workshop, Estes Park, Colo., ARL/NOAA, U.S. Dept. of Comm., Boulder, Colo., 65 p.

Angell, J.A., and A. Korshover (1977): Estimate of the global change in temperature, surface to 100 mb, between 1958 and 1975. Mon. Wea. Rev., 105:375-385.

Berger, D. S. (1976): The sunburning ultraviolet meter: design and performance. Photochem. Photobiol., 24:587.

Berri, G. J., and J. T. Peterson (1978): Dependence of atmospheric turbidity at Raleigh, N.C., on air mass trajectories. NOAA Tech. Memo. ERL ARL-68, Boulder, Colo., 16 p.

Bischof, Walter (1975): The influences of the carrier gas on the infrared gas analysis of atmospheric CO_2. Tellus, 27:59-61.

Bodhaine, B. A. (1978): The Mauna Loa four-wavelength nephelometer: instrument details and three years of operation. NOAA Tech. Rep. ERL 396-ARL 5.

Bodhaine, B. A., and B. G. Mendonca (1974): Preliminary four-wavelength nephelometer measurements at Mauna Loa Observatory. Geophys. Res. Letters, 1:119.

Bolin, B., and C. D. Keeling (1963): Large-scale atmospheric mixing as deduced from the seasonal and meridional variations of carbon dioxide. J. Geophys. Res., 68:3899-3920.

Carroll, J. J., K. L. Coulson, R. H. Hamilton, and B. Jackson (1977): Atmospheric processes and energy transfers at the South Pole. Antarct. J., 12:164-165.

Cess, R. D. (1976): Climate change: An appraisal of atmospheric feedback mechanisms employing zonal climatology. J. Atmos. Sci., 33:1831-1843.

Costrell, L. (1973): CAMAC instrumentation system - introduction and general description. IEEE Trans. on Nuclear Sci., NS-20(2):3-8.

Coulson, K. L. (1977): Atmospheric turbidity determinations by skylight measurements at the Mauna Loa Observatory. Contrib. in Atmos. Sci., no. 13, Univ. of Calif., Davis, Calif.

Coulson, K. L. (1978): Zenith skylight characteristics in the sunrise period at Mauna Loa. In Mauna Loa Observatory; a 20th anniversary report, J. Miller, ed., Special Rep., NOAA Air Resources Laboratories, Rockville, Md., 105-113.

Court, A. (1978): Comments on 'Percent of possible sunshine and total cloud cover.' Mon. Wea. Rev., 106:570-572.

Cram, R. S., and K. J. Hanson (1977): The United States B-scale surface radiation subprogram of GATE: Instrumentation and data validation. NOAA Tech. Memo. ERL ARL-65, Boulder, Colo., 88 p.

DeLuisi, J. J. (1978): Umkehr vertical-ozone profile errors caused by the presence of stratospheric aerosols. J. Geophys. Res. (In press.)

DeLuisi, J. J., and B. M. Herman (1977): Estimation of solar radiation absorption by volcanic stratospheric aerosols from Agung using surface-based observations. J. Geophys. Res., 82:3477-3480.

DeLuisi, J. J., K. J. Hanson, and B. G. Mendonca (1978): Estimation of changes in the global albedo and temperature due to stratospheric aerosols from Agung and subsequent volcanic activity. J. Geophys. Res. (Being revised.)

Dyer, A. J. (1974): The effect of volcanic eruptions on global turbidity and an attempt to detect long-term trends due to man. Q.J. Roy. Meteorol. Soc., 100:563-571.

Ellis, H. T., and R. F. Pueschel (1971): Solar radiation: absence of air pollution trends at Mauna Loa. Science, 172:845-846.

Feely, H. W., H. L. Volchok, E. P. Hardy, Jr., and L. E. Toonkel (1978): Worldwide deposition of ^{90}Sr through 1976. Environ. Sci. and Tech. (In press.)

Fegley, R. W. (1977): The NOAA stratospheric lidar project; recent results. Presented at 8th Int. Conf. on Laser Atmos. Studies, Philadelphia, Pa., June 1977, Amer. Meteorol. Soc.

Fegley, R. W. (1978a): The geophysical monitoring for climatic change stratospheric monitoring project - 1977 Annual Report. Presented at GMCC 1978 Annual Meeting, Hilo, Hawaii, January 25-27, 1978.

Fegley, R. W. (1978b): The Air Resources Laboratories stratospheric lidar project; 1976 results. NOAA Tech. Rep. ERL 400-ARL 6, 9 p.

Fegley, R. W., and H. T. Ellis (1975a): Lidar observations of a stratospheric dust cloud layer in the tropics. Geophys. Res. Letters, 2(4):139-141.

Fegley, R. W., and H. T. Ellis (1975b): Optical effects of the 1974 stratospheric dust cloud. Appl. Optics, 14(8):1751-1752.

Fegley, R. W., and C. M. Penney (1978): An experimental attempt to measure atmospheric ozone using ultraviolet laser radar at Mauna Loa Observatory. NOAA Tech. Memo. (In press.)

Fegley, R. W., E. W. Barrett, and H. T. Ellis (1978a): Lidar measurements at Mauna Loa Observatory. In Mauna Loa Observatory; a 20th anniversary report, J. Miller, ed., Special Rep., NOAA Air Resources Laboratories, Rockville, Md., 59-65.

Fegley, R. W., H. T. Ellis, and J. L. Heffter (1978b): A volcanic cloud in the troposphere. J. Appl. Meteorol. (Submitted.)

Galloway, J. N., and G. E. Likens (1976): Calibration of collection procedures for the determination of precipitation chemistry. Water Air Soil Pollut., 6:241-258.

Goetz, F. W. P. (1931): Zum Strahlungsklima des Spitzbergen Sommers. Gerlands Beitrage Zur Geophys., 31:119-154.

Goetz, F. W. P., A. R. Meetham, and G. M. B. Dobson (1934): The vertical distribution of ozone in the atmosphere. Proc. Roy. Soc. London, A145: 416-446.

Goldberg, B., and W. H. Klein (1977): Variations in the spectral distribution of daylight at various geographical locations on the earth's surface. Solar Energy, 19:3-13.

Goldberg, B., and W. H. Klein (1978): A simplified model for determining the spectral quality of daylight and the availability of solar energy at any location. 7th Int. Solar Energy Conf., New Delhi, India.

Green, A. E. S., G. B. Findley, Jr., K. F. Klenk, W. M. Wilson, and T. Mo (1976): The ultraviolet dose dependence of non-melanoma skin cancer incidence. Photochem. Photobiol., 24:353.

Hanson, K. J. (1978): Method of determining standard-year, clear-sky, solar-noon irradiance (SYI) values for 26 stations over the contiguous United States. SOLMET, vol. II, Users Manual, Hourly solar radiation-surface meteorological observations, Final Rep., NOAA Environmental Data Service, Asheville, N.C. (In press.)

Heath, D. F., C. L. Mateer, and A. J. Krueger (1973): The Nimbus-4 backscatter ultraviolet (BUV) atmospheric ozone experiment, two years operation. Pure and Appl. Geophys., 106-108:1238-1253.

Hogan, A. (1975): Antarctic aerosols. J. Appl. Meteorol., 14:550-559.

Hogan, A. (1976): Aerosol of the trade winds region. J. Appl. Meteorol., 15:611-619.

Hogan, A., and S. Barnard (1978): Seasonal and frontal variation in Antarctic aerosol concentrations. J. Appl. Meteorol., 17:1458-1465.

Hogan, A., W. Winters, and G. Gardner (1975): A portable aerosol detector of high sensitivity. J. Appl. Meteorol., 14:39-45.

Hoyt, D. V. (1976): The radiation and energy budgets of the Earth using both ground-based and satellite-derived values of total cloud cover. NOAA Tech. Rep. ERL 362-ARL 4, 124, p.

Hoyt, D. V. (1977a): Percent of possible sunshine and total cloud cover. Mon. Wea. Rev., 105:648-652.

Hoyt, D. V. (1977b): Comments on 'Climate change: An appraisal of atmospheric feedback mechanisms employing zonal climatology.' J. Atmos. Sci., 34:1824-1825.

Hoyt, D. V. (1978a): A model for the calculation of solar global insolation. Solar Energy, 21:27-35.

Hoyt, D. V. (1978b): Reply (to Court). Mon. Wea. Rev., 106:572-573.

Hoyt, D. V. (1978c): Interannual cloud cover variations in the contiguous United States. J. Appl. Meteorol., 17:354-357.

Hoyt, D. V. (1979a): The Smithsonian Astrophysical Observatory solar constant program. Revs. of Geophys. and Space Res. (In press.)

Hoyt, D. V. (1979b): Atmospheric transmission from the Smithsonian Astrophysical Observatory pyrheliometric measurements, 1923-1954. J. Geophys. Res. (Submitted.)

Hoyt, D. V. (1979c): Theoretical calculations of the true solar noon atmospheric transmission. SOLMET, vol. II, Users Manual, Hourly solar radiation-surface meteorological observations, Final Rep., NOAA Environmental Data Service, Asheville, N.C. (In press.)

Keeling, C.D., R. B. Bacastow, A. E. Bainbridge, C. A. Ekdahl, Jr., P. R. Guenther, L. S. Waterman, and J. F. S. Chin (1976): Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii. Tellus, 28:538-551.

Kelley, J. J., Jr. (1969): An analysis of carbon dioxide in the Arctic atmosphere near Pt. Barrow, Alaska 1961 to 1967. Scientific Rep., Office of Naval Res., Contract N00014-67-A-01030-0007, Univ. of Washington, Seattle.

Klein, W. H., and B. Goldberg (1974): Solar radiation measurements 1968-1973. Smithsonian Rad. Bio. Lab., Rockville, Md., Smithsonian Instit., Wash., D.C.

Klein, W. H., and B. Goldberg (1976): Solar radiation measurements 1974-1975. Smithsonian Rad. Bio. Lab., Rockville, Md., Smithsonian Instit., Wash., D.C.

Klein, W. H., and B. Goldberg (1978): Monitoring UVB irradiances at three latitudes. 7th Int. Solar Energy Conf., New Delhi, India.

Klein, W. H., B. Goldberg, and W. Shropshire, Jr. (1977): Instrumentation for the measurement of the variation, quantity and quality of sun and sky radiation. Solar Energy, 19:115-122.

Mendonca, B. G., K. Hanson, and J. J. Deluisi (1978): Volcanically related secular trends in atmospheric transmission at Mauna Loa Observatory, Hawaii. Science, 202:513-515.

Pales, J. C., and C. D. Keeling (1965): The concentration of atmospheric carbon dioxide in Hawaii. J. Geophys. Res., 70:6053-6076.

Pearman, G. I. (1977): Further studies of the comparability of baseline atmospheric carbon dioxide measurements. Tellus, 29:171-181.

Pearman, G. I., and J. R. Garratt (1975): Errors in atmospheric CO_2 concentration measurements arising from the use of reference gas mixtures different in composition to sample air. Tellus, 27:62-65.

Peterson, J. T. (1977): Statistical editing of background carbon dioxide measurements. Preprints, 5th Conf. on Probability and Statistics in Atmos. Sci., Las Vegas, Nev., Amer. Meteorol. Soc., 158-161.

Peterson, J. T., and T. L. Stoffel (1978): Urban-rural solar irradiance measurements at St. Louis. Preprints, 3rd Conf. on Atmos. Radiation, Davis, Calif., Amer. Meteorol. Soc., 319-321.

Peterson, J. T., W. D. Komhyr, T. B. Harris, and J. F. S. Chin (1977): NOAA carbon dioxide measurements at Mauna Loa Observatory, 1974-1976. Geophys. Res. Letters, 4(9):354-356.

Pollak, L. W., and A. L. Metnieks (1960): Intrinsic calibration of the photoelectric nucleus counter, model 1957, with convergent light beam. Tech. Note 9, Contract AF61, (052)-26, School of Cosmic Physics. Dublin Institute for Advanced Studies, Dublin, Ireland, 62 p.

Pollack, J. B., et al. (1976): Volcanic explosion and climate change: A theoretical assessment. J. Geophys. Res., 81:1071-1083.

Porch, W. M., D. S. Ensor, R. J. Charlson, and J. Heintzenber (1973): Blue moon: is this a property of background aerosol? Appl. Opt., 12:34.

Rahn, K. A. (1978): The Arctic air-sampling network. Arctic Bull. (Submitted.)

Rahn, K. A., R. D. Borys, and G. E. Shaw (1977a): The Asian source of Arctic haze bands. Nature, 268:713-715.

Rahn, K. A., R. D. Borys, and G. E. Shaw (1977b): Particulate air pollution in the Arctic: large-scale occurrence and meteorological controls. Proc. 9th Int. Conf. on Atmos. Aerosols, Condensation and Ice Nuclei, Galway, Ireland, 21-27 September 1977.

Rah, K. A., R. D. Borys, and G. E. Shaw (1978): Asian desert dust over Alaska: Anatomy of an Arctic haze episode. Proc. AAAS Symp. "Desert Dust: Origin, Characteristics, and Effect of Man," Denver, Colo., 22-23 February 1977, Univ. of Arizona Press. (In press.)

Rasmussen, R. A. (1978): Interlaboratory comparison of fluorocarbon measurements. Atmos. Environ. (In press.)

Rich, T. A. (1966): Apparatus and method for measuring the size of aerosols. J. Rech. Atmos., 2:79-86.

Schwerdtfeger, W. (1970): Climate of the Antarctic. In Climate of Polar Regions, S. Orvig, ed., World Survey of Climatology, vol. 14, Elsevier, London, 253-356.

Scotto, J., T. Fears, and G. Gori (1976): Measurements of UV radiation in the U.S. and comparisons with skin cancer data. U.S. Dept. of Health, Education and Welfare, NIH no. 76-1029.

Shives, F. G., and E. Robinson (1977): Site evaluation for geophysical monitoring for climatic change-II. Final Rep., Chem. Eng. Dept., Washington State Univ., 50 p.

Sinclair, D. (1972): A portable diffusion battery. AIHA J., 729-735.

Spurny, K. R., J. P. Lodge, E. R. Frank, and D. C. Sheesley (1969): Aerosol filtration by means of Nuclepore filters. Environ. Sci. Technol., 3:464-468.

U. S. Geological Survey (1978): Research and monitoring of precipitation chemistry in the United States--present status and future needs. USGS, Dept. of Interior, Reston, Va., 64 p.

Volchok, H. L., and R. T. Graveson (1976): Wet/dry fallout collection. Proc. 2nd Fed. Conf. on the Great Lakes, Great Lakes Basin Comm.

Volz, F. E. (1975): Volcanic twilights from the Fuego eruption. Science, 189:48-50.

Volz, F. E. (1976): Trend of twilight color ratios and converted LIDAR data of the Fuego dust cloud. Topical Meeting: Atmospheric aerosols, their optical properties and effects, Williamsburg, Va., 13-15 December 1976, NASA Cp-2004, Paper MB9.

Winters, W., S. Barnard, and A. Hogan (1977): A portable photo recording Aitken counter. J. Appl. Meteorol., 16:992-996.

11. GMCC STAFF

Director's Office
- *Kirby J. Hanson, Director
- Helen C. Cook, Secretary
- Ernest Daniel, Administrative Officer
- Constance Shilvock, Jr. Fellow

Acquisition and Data Management Group
- *Gary A. Herbert, Chief
- Arija Bottomley, Clerk
- Connie Carla, Secretary
- *Joyce Harris, Computer Programmer
- *Lee Johnson, Computer Programmer
- James Jordan, Electronic Engineer
- *Milton S. Johnson, Electronic Technician
- Steven Waas, Jr. Fellow

Monitoring Trace Gases Group
- *Walter D. Komhyr, Chief
- Connie Carla, Secretary
- *Robert Grass, Physicist
- *Thomas B. Harris, Meteorological Technician
- *Samuel Oltmans, Physicist
- *Thayne Thompson, Physicist
- *Lee Waterman, Chemist

Aerosols and Radiation Monitoring Group
- *John DeLuisi, Chief
- *Barry A. Bodhaine, Research Physicist
- *Ronald Fegley, Research Physicist
- *Bernard Mendonca, Research Meteorologist
- Gail M. Phillips, Secretary

Analysis and Interpretation Group
- *James T. Peterson, Chief
- *Douglas V. Hoyt, Physicist
- Gail M. Phillips, Secretary
- Cheryl Reynolds, Jr. Fellow
- Thomas Stoffel (CIRES)

Mauna Loa Observatory
- *John M. Miller, Director
- John F. S. Chin, Physicist
- Richard Cram, Meteorologist
- Howard Ellis, Physicist
- Judith B. Pereira, Secretary
- Mamoru Shibata, Electronic Technician
- *Alan M. Yoshinaga, Analytical Chemist

Barrow Observatory
- Emerson G. Wood, Lt. NOAA Corps, Station Chief
- *Thomas DeFoor, Lt. NOAA Corps, Station Chief
- Steven Hill, Electronic Technician

Samoa Observatory
- *Donald W. Nelson, Station Chief
- Larry Westerman, Physical Scientist

South Pole Observatory
- *Brad Halter, Physical Scientist
- Gary Rosenberger, Electronic Technician

---

*Contributors to Summary Report

☆ U. S. GOVERNMENT PRINTING OFFICE 1979 - 677-072/1254 Reg. 8