clear skies and at low surface temperatures. Many columnar crystals had complex inner structures that often were asymmetric (figure 4). Nonuniform growth conditions under the extremely low temperatures probably account for the complex shapes.

Electron microscopic examinations of pencil and triangle-shaped ice crystals revealed no detectable nucleus, which confirms that these crystals were formed by homogeneous nucleation. On the other hand, the bullet crystals, presumably formed in high clouds, had several nuclei.

An upslope wind from the grid north was again confirmed as the favored wind for the formation of ice crystals at South Pole Station.

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Geophysical monitoring for climatic change (GMCC)

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From November 1977 to November 1978, the Geophysical Monitoring for Climatic Change (GMCC) program continued operations at Amundsen-Scott (South Pole) Station, one of the program's four baseline stations. The purpose of the program is to measure trace constituents of the atmosphere relevant to the study of climatic change and the anthropogenic impact on such change. South Pole operations in 1977–78 consisted of taking continuous measurements of such parameters as carbon dioxide, surface ozone, meteorology, solar radiation, and aerosols, as well as maintaining other discrete programs and cooperating in other research efforts.

Continuous measurement activities included the following:

1. Carbon dioxide. An infrared analyzer was used to continuously measure the atmospheric concentration of carbon dioxide (CO_2). Twice monthly flask air samples were taken through the analyzer sampling line for comparison. Statistical analysis of the continuous data showed that a weekly sampling could give representative data on the CO_2 trend at the South Pole. Consequently, in November 1978, the continuous CO_2 analyzer was shut down and a weekly hand-aspirated flask sampling routine commenced. Continuous measurement of CO_2 is anticipated to resume in 1979 when the conversion of standard gases from CO_2-in-N_2 to CO_2-in-air is completed.

During 1978, the annual mean South Pole CO_2 concentration was approximately 1.1 parts per million (ppm) greater than the annual mean for 1977. At GMCC's Mauna Loa baseline station, the annual mean increase detected was about 1.5 ppm. These changes are part of the long-term increase observed worldwide. The seasonal variation in concentration, marked by an early winter minimum and early summer maximum (Keeling et al., 1976), is very evident in figure 1.

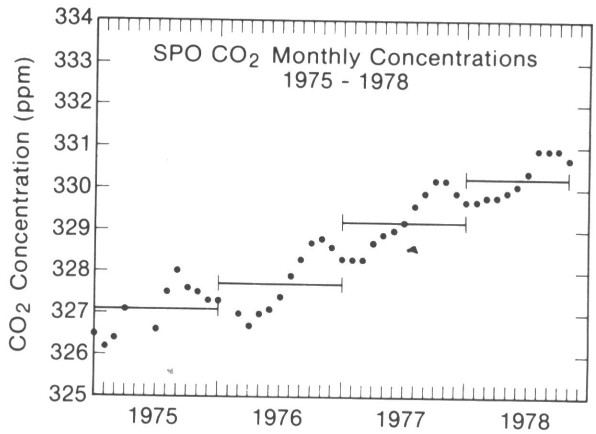

Figure 1. GMCC South Pole provisional monthly mean carbon dioxide (CO_2) concentrations. Data either analyzed on, or corrected to, Boulder/GMCC lira 202 continuous analyser, and expressed in Scripps 1959 adjusted manometric index scale.

2. Surface ozone. Two instruments were used to measure ozone concentration. One is a photometer that uses ultraviolet absorption by ozone. The other uses an electrochemical concentration cell, with ozone as the oxidant. The expected annual variation in concentration, with a summer minimum and winter maximum (Oltmans and Komhyr, 1976), was observed during 1978.

3. Meteorology. Continuous measurements of winds, pressure, air and snow temperature, and atmospheric moisture were made throughout the year. The wind and air temperature sensors were located on a tower 30 meters grid north of the clean air facility (CAF). The snow temperature sensor was positioned between the tower and CAF. The pressure sensor was mounted inside the building and the moisture monitor was attached to the gas-sampling stack.

The mean temperature for the period from November 1977 to November 1978 was −49.4° C. This is 0.1° C less than the mean for the previous 20-year period of South Pole Station existence. A 56-degree temperature range was observed during this year, with a maximum of −21° C on 3 January 1978 and a minimum of −77° C on 17 September 1978. In five periods during the winter, temperatures sank below −73.3° C (−100° F) for more than 12 hours at a time. Two of these, 19–20 June and 16–18 August, were also accompanied for a time by winds of from 11 to 13 knots, creating wind chills down to −113° C.

4. Solar radiation. Austral summer continuous measurements were of direct and global irradiance. Direct irradiance was obtained with a normal incidence pyrheliometer mounted on a solar tracker. Global irradiance was measured with four pyranometers with quartz, GG–22, OG–1, and RG–8 hemispheric filters, and one ultraviolet pyranometer. In addition, discrete direct irradiance measurements were taken three times every 24 hours on an unobscured sun using another pyrheliometer with a rotating filter wheel (quartz, OG–1, RG–2, RG–8). Figure 2 shows representative values.

5. Aerosols. Measurement activities consisted of measuring Aitken nuclei concentrations on a yearlong continuous basis, three times every 24 hours, and intermittently, using three different instruments—one automatic and two manual condensation nuclei counters. Figure 3 presents a time history of aerosol concentration trends. The characteristic temperature inversion, strong during the austral winter, allows surface aerosol depletion (Hogan and Bernard, 1978). Concentrations of less than 10 nuclei per cubic centimeter were detected throughout June, July, and August 1978.

All measurements were carried out from the CAF, described by Peterson (1978). The GMCC measurement instruments received ambient air from a dual sampling stack system, one stack being for gases and the other for aerosols. The intakes were 14 meters above the snow surface, and lines ran from the stacks to the instruments. Flow rates from the gas stack were adjusted at the instruments; laminar flow was maintained through the aerosol stack.

A centralized data acquisition system was used to receive and record the inputs from the measuring instruments. The system consisted of a minicomputer, tape drive, multiplexer digitizer, and cronolog clock. Analog signals from the measurement instrumentation were sent to the multiplexer for digitization and were recorded on tape as 10-minute voltage sums and hourly values in scientific units. Software controlled this process and made it possible to change scaling factors, initiate calibrations, and check incoming voltages.

In addition to the measurement programs discussed above, three discrete programs were maintained during 1978. In one program, during the austral summer, a hand-held sunphotometer was used to take atmospheric turbidity measurements three times every 24 hours when the sun was not obscured by clouds.

The second program involved using a Dobson spectrophotometer throughout the austral summer to measure total atmospheric ozone. Observations were taken three times every 24 hours, and quasi-simultaneous comparisons of all observation types and wavelengths were made whenever possible. In addition, focused moon observations were taken during the winter whenever moonlight was strong enough to be detected by high instrument sensitivity. (South Pole Station is a part of the United States Dobson spectrophotometer network.)

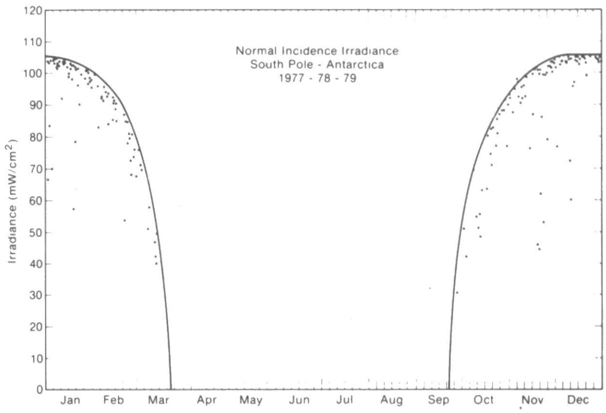

Figure 2. Normal incident solar irradiance values for clear sky conditions at South Pole. Hand held pyrheliometer measurements taken on days when sun clearly visible. Wide scatter of data attributed to presence of ice crystals on some of measurements days. Envelope describes upper limit of measured irradiances obtained for three-year period. For days when no ice crystals were evident, scatter about mean of data is approximately ±4.0% for values in the 90 to 105 mw per square centimeter range.

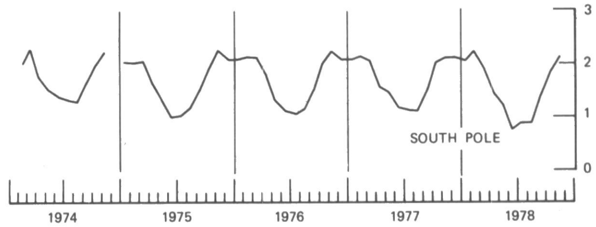

Figure 3. Monthly geometric mean concentrations of Aitken nuclei for South Pole.

The third program involved fluorocarbon analysis. To analyze F-11, F-12, and N_2O, samples were drawn from the gas stack into 300-millimeter polished stainless steel cylinders. This was done bimonthly during the summer and monthly during the winter.

The GMCC program's South Pole Station is operated by the Air Resources Laboratory of the National Oceanic and Atmospheric Administration (NOAA) with support from the National Science Foundation. During the 1977–78 yearlong season, the station was operated by John Osborn (physical scientist) and Larry Smith (electronics engineer).

During 1977–78, the station's personnel also cooperated in other research efforts, including projects of the Scripps Institute of Oceanography; U.S. Department of Energy; NOAA Atmospheric Physics and Chemistry Laboratory; Environmental Data and Information Service, University of California, San Diego; and the Arctic and Antarctic Research Institute, Leningrad, U.S.S.R.

For a review of all activities since 1972, see GMCC program summary reports 1–6. Besides data acquisition and achival work, the GMCC organization is actively involved in atmospheric research. Data analysis and interpretation and research publications within the organization are part of the continuing work performed at the Environmental Research Laboratories, which are located in Boulder, Colorado.

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Lidar operations at Palmer Station

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In December 1977, we set up a two-channel dye laser lidar instrument at Palmer Station. The instrument recorded data during the austral winter of 1978 and later was in operation for the austral winter of 1979. The objective of this program has been to determine the occurrence and vertical profiles of ice crystals, water drops, and mixed-phase clouds at Palmer Station and to relate these measurements to observed meteorological conditions.

The technique employed for ice/water discrimination is the measurement of depolarization in backscatter of a polarized laser beam. We have employed this technique previously in measurements at the South Pole (Smiley, Morley, and Whitcomb, 1976; Smiley et al., 1979; Smiley and Morley, 1979). Sassen (1978) gives linear depolarization ratios for backscatter from various types of ice particles: 0.03 to 0.5 for mixed-phase clouds; 0.5 for pure ice crystal layers; 0.5 for snowflakes; 0.6 for rimed particles; and 0.7 for graupel. The depolarization for pure spherical water drop clouds should be zero for single scattering.

In principle, ice and water can be discriminated in these measurements. However, some complications can arise as a result of multiple scattering and crystal orientation. Multiple scattering causes depolarization in dense water drop clouds; nevertheless, the multiple scattered radiation produces a spatial delay that shows up as a delayed non-zero depolarization. A high degree of orientation of crystals, plates in particular, can produce very small values of depolarization, possibly allowing an ice layer to be mistaken for a water drop layer. We will study this phenomenon further in laboratory scattering experiments and also through lidar measurements in cirrus in Nevada.