1. Observatory Operations and Meteorology

1.1. Mauna Loa Observatory

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1.1.1. Operations

The construction of the new building that houses the Doppler lidar built by Michigan Aerospace is complete. The Doppler lidar measures the wind from the ground, up through the troposphere, and is operated remotely over the Internet. The project is funded by NOAA and managed by the University of New Hampshire. The resulting wind profiles are used by the University of Hawaii meteorology group to make upper air forecasts for the telescopes on Mauna Kea volcano 35 km to the north of Mauna Loa volcano.

Permission was given to a Taiwanese group (Academia Sinica Institute of Astronomy and Astrophysics) to install the array for Microwave Background Anisotrophy (AMiBA) radio antenna project at MLO. A depression will be excavated east of the MLO buildings for the receiving structure that will not extend above the horizon as seen from the radiation platform. A test stand was constructed above the Arizona building for the prototype receivers; they will be removed once testing is complete. The solar dome and the Arizona building house the electronics for the test. The AMiBA antenna will be operated on clear nights by two AMiBA staff members. At the end of the 5-year operation period, the telescope will be removed and the infrastructure will become the property of MLO.

Not quite as many visiting instruments were sent to MLO for short-term solar sunrise calibrations as in recent years. All of the groups that did come have been to MLO before. A Japanese group left an instrument running unattended for several weeks before returning to pack and ship the instrument back to Japan. Computer network connections were added to accommodate them.

Two new contract employees were added to MLO staff to assist with new programs and to develop software for the lidar program.

Outreach

There were continuing requests for groups to visit the observatory; many of them came via the Internet which was also used to obtain visitor information and to make arrangements. Several University of Hawaii groups visited MLO as did groups attending science conferences on both Oahu and the Big Island. The Discovery channel filmed part of a program on climate change at the observatory, and journalists from *USA Today* and *Frankfurter Allgemeine Zeitunga* reported on MLO activities.

Awards were given by the MLO employees' organization for environmentally related projects at the Hawaii County Science Fair. Two high school summer students were mentored during June 2002 on short data analysis projects that were part of the University of Hawaii at Hilo's Upward Bound project. Also two university students, one from the University of Pennsylvania and the other from the University of Hawaii at Hilo, worked summers at MLO on the lidar program.

The Volcano Gas Observatory Network (VOGNET) program, a cooperative effort between the Big Island high schools and MLO to monitor volcanic pollution (vog), is in its eighth year of operation. Beginning in January 2002, PC-controlled continuous condensation nuclei (CN) counters operated at six high schools and in the MLO Hilo office. The CN counters were designed at MLO and built by the students and teachers. Continuous CN measurements are taken throughout the school year from September through May. During the summer school break, the instruments are calibrated at the MLO office and a field experiment is performed. In the summer of 2002, the counters were deployed on the slope above the Kona coast between sea level and 1400 m to investigate the diurnal changes in vog particle concentration as a function of altitude. The study found that the highest particle concentrations occur during the day in a broad layer between 200 and 900 m above sea level and that air with near-background CN concentrations persists at sea level. In the summer of 2003 the counters were deployed at various sites around Hilo to measure anthropogenic CN concentrations during trade-wind conditions. In the fall of 2003 the counter at windward Pahoa High School was relocated to the Pu'uhonua o Honaunau National Historic Park, a sea-level site on the Kona coast. Data from this site confirmed the presence of a persistent layer of low particle concentration at sea level.

Mountain View Elementary School students visited MLO's Hilo office on 16 October 2003. Prior to their visit, the students completed a scavenger hunt assignment to familiarize them with the purpose and operations of the observatory. During the visit, MLO staff members manned activity centers with interactive displays relating to weather and how observations are conducted. A Web camera broadcast the activity live to the Internet.

Computers/Network

Major changes to the MLO network occurred in 2002 and 2003. At the mountain site, network connectivity was changed from two 56 KB lines to two 1.45 Mbs (T1) lines. One T1 line is managed by National Center for Atmospheric Research (NCAR) and provides connectivity for the High Altitude Observatory (HAO), the Global Oscillation Network Group (GONG), and the University of New Hampshire GroundWinds instrument (mlo.noaa.gov/projects/fproject.htm). The second T1 line is managed by and provides connectivity for MLO programs, Network for the Detection of Stratospheric Change (NDSC) operations, other cooperative programs, and the new AMiBA project. Because of this reconfiguration, the fiber optic cabling at the mountain site had to be changed to fit the new topology.

At the Hilo office, the 128-K frame relay line was changed to a digital subscriber line (DSL) with 384 KB up and 1.5 M down. DSL is more cost effective than the old frame relay line. The U.S. Fish and Wildlife Service (FWS), Hilo office, once supported by MLO, obtained their own network line. Consequently, the wireless bridge between the MLO and the FWS offices was shut down.

The Internet service provider was changed from the University of Hawaii to Verizon at both the mountain site and the Hilo office.

As a result of this change, a new set of Internet Protocol (IP) addresses was assigned for all of the computers at both sites. The domain name at the Hilo office remains "mlo.noaa.gov," but the mountain site was changed to "mtn.mlo.noaa.gov." A wireless network was set up at both the Hilo and the mountain sites for use by visitors and for mobile computing.

Computer security was increased with the addition of firewall appliances at both the mountain and the Hilo sites. Also, a Virtual Private Network (VPN) device was added at the mountain site and biometric fingerprint scanners were added to all staff computers at the Hilo office.

A Global Positioning System (GPS) time-server device, provided by the AMiBA project, was set up on 4 December 2003 at the observatory site. The new server can be used to synchronize the clocks on each computer connected on the network.

Five new pages were added to the MLO Web site: an SO_2 page, a GroundWinds page, a Visitor Information Request page, a streaming video from the Web cameras, and the "Webmet" page. The Webmet system displays real-time meteorological and solar data that can be accessed from the MLO Web site.

In July 2002 a new camera was set up at the Smithsonian Institute telescope on Mauna Kea that faces south to the Mauna Loa volcano. This camera provides live streaming video of cloud conditions around MLO and is accessible from the MLO Web site.

1.1.2. Programs

Table 1.1 summarizes the programs in operation or terminated at MLO during 2002 and 2003. Relevant details on some of the respective programs follow:

Gases

Flask sampling. The weekly CO_2, CH_4, O_2, and other flask sampling programs were carried out at MLO and at Cape Kumukahi according to schedule. A prefabricated sampling building was placed at Cape Kumukahi in August 2003 by Scripps Institution of Oceanography, University of California, San Diego (SIO), and the University of Hawaii, Manoa. There are plans to put aerosol and oxygen analyzers in this building as well as the pumps presently used for taking weekly flask samples.

Carbon dioxide. The CMDL Siemens Ultramat-3 infrared (IR) CO_2 analyzer operated without problems during 2002 and 2003. A new computer was installed in November 2003, and the system was converted to measure three reference gases every hour. Nighttime CO_2 emissions from the Mauna Loa volcano have undergone a steady decline since the 1984 eruption and are now at the record low levels measured in the early 1970s.

Carbon monoxide. A Trace Analytical RBA3 reduction gas analyzer measures CO at MLO. In August 2003 two staff members from the World Meteorological Organization (WMO) did an audit of the CO system with the help of CMDL staff. Beginning in the summer of 2003, analyzer lamps were purchased from a new supplier. The new lamps have significantly improved the precision of the CO measurements.

Methane. The Hewlett-Packard (HP6890) methane gas chromatograph (GC) system operated throughout 2002 and 2003. From June to August 2003 a contaminated O_2/N_2 tank caused some loss of precision in the measurements. In November 2003 the system was upgraded by staff from CMDL Boulder.

Sulfur dioxide. A TECO 43-S pulsed-fluorescence analyzer is used to measure SO_2 with a detection limit of 50 parts per trillion (ppt) for a 1-hour measurement. Each hour samples are taken sequentially from inlets at 4, 10, 23, and 40 m on the tower, followed by a filtered zero measurement. A single-point calibration is made once per day by the injection of calibration gas into the airstream at the 40-m intake. The system primarily measures SO_2 from both the Kilauea and Mauna Loa volcanoes. Trace amounts of SO_2 can sometimes be detected in the more severe Asian pollution episodes. The complete hourly data set from 1994 to 2003 is available on the MLO Web site.

Ozone monitoring. The 2002 and 2003 MLO ozone monitoring program consisted of three measurement foci: continuous MLO surface ozone monitoring using a Dasibi model 1003-AH ultraviolet (UV) absorption ozone monitor, daily total and Umkehr ozone profile measurements using a computer-based automated Dobson instrument (Dobson 76), and ozone profile measurements based on weekly ascents of balloonborne electrochemical concentration cell (ECC) ozonesondes released from the NWS station at the Hilo airport.

The Dobson 76 operated daily on the weekdays throughout the period along with daily AM/PM Umkehr runs. Summer intercomparisons with a standard Dobson 83 instrument occurred in both 2002 and 2003. The instrument was maintained as needed with the pedestal unit, the wedge motor, and the photon-coupler interrupter replaced. Also, repairs were made on the dome (hatch and shutter) the lower shutter assembly, and adjustments were made to miscellaneous motors, belts, and tension springs.

The Dasibi program operated normally throughout 2002 and 2003. The Dasibi was calibrated, yearly maintenance was carried out, and absorption tubes were cleaned. On 16 January 2002 a Thermo Environmental Instruments, Inc. (TEI) UV photometric ambient ozone analyzer, that ran side by side with the Dasibi and used the same stack and computer, was installed. During the WMO audit of the surface ozone equipment in August 2003, the Dasibi unit malfunctioned. The instrument was replaced with a TEI 49C unit; both TEI's operate using the old Dasibi software.

Ozonesondes were launched weekly from the Hilo airport. There were 56 flights in 2002 and 50 flights in 2003. By the end of 2003, over 600 digital ozonesondes flights have been made from Hilo since the inception of the program. On 11 August 2002, ozonesondes were launched on an almost daily schedule between 1800 local standard time (LST) and 2100 LST to support the ozone intercomparison experiment at MLO. Also beginning in March 2002 several combined ozone and water-vapor sonde flights were made.

Halocarbons and other atmospheric trace gas species. The Halocarbons and other Atmospheric Trace Species program (HATS) operated normally in 2002 and 2003 with the usual maintenance and replacement of parts including electron capture detectors, traps, and columns. In August 2003 cartridges were ordered to replace the original Supelco oven components and a carbon sieve was installed in the P5 line. Problems persisted with channel 4's trap and column. Repairs were completed by late 2003 and the system is fully operational.

Table 1.1. Summary of Measurement Programs at MLO in 2002-2003

Program/Measurement	Instrument	Sampling Frequency
Gases		
CO_2	Siemens Ultramat-3 NDIR analyzer*	Continuous
CO	Trace Analytical RGA3 no. R5*	Continuous
CO_2, CH_4, CO, $^{13}C/^{12}C$, $^{18}O/^{16}O$ of CO_2, H_2, N_2O, SF_6, and ^{13}C of CH_4	2.5-L glass flasks, MAKS pump unit	1 pair wk^{-1}
	2.5-L glass flasks, through analyzer	
	AIRKIT pump unit, 2.5-L glass flasks†	1 pair wk^{-1}
CH_4	HP6890GC*	Continuous
SO_2	TECO model 43-S pulsed-fluorescence analyzer; 4, 10, 23, 40 m*	Continuous
Surface O_3	Dasibi 1003-AH UV absorption ozone monitor (End ed 08/03)*	Continuous
	TEI Model 49 UV absorption ozone monitor* and	
	TEI Model 49C UV absorption ozone monitor (Began 8/03)*	
Total O_3	Dobson spectrophotometer no. 76*	3 day^{-1}, weekdays
O_3 profiles	Dobson spectrophotometer no. 76* (automated Umkehr method)	2 day^{-1}
	Balloonborne ECC sonde	1 wk^{-1}
N_2O, CFC-11, CFC-12, CFC-113, CH_3CCl_3, CCl_4, SF_6, HCFC-22, HCFC-21, HCFC-124, HCFC-141b, HCFC-142b, CH_3Br, CH_3Cl, CH_3I, CH_2Cl_2, $CHCl_3$, C_2Cl_4, H-1301, CH_2Br_2, $CHBr_3$, H-1211, HFC-134a, HFC-152a, C_6H_6, COS	850-mL, 2.5-L, or 3-L stainless-steel flasks	1 pair wk^{-1}
CFC-11, CFC-12, CFC-113, N_2O, CH_3CCl_3, CCl_4, CH_3Br, CH_3Cl, H-1211, SF_6, HCFC-22, COS, $CHCl_3$, HCFC-142b	Automated CATS GC	1 sample h^{-1}
Aerosols		
Condensation nuclei	TSI 3010 CN	Continuous
Vog Monitoring Network (VOGNET)	Condensation nuclei counter (spread throughout the island)	Continuous
Optical properties	Three-wavelength nephelometer; 450, 550, and 700 nm wavelengths (TSI)	Continuous
	Light absorption photometer (Radiance Research PSAP)	
Aerosol light absorption (black carbon)	Aethalometer**	Continuous
Stratospheric and upper tropospheric aerosols	Nd:YAG lidar: 532-, 1064-nm wavelengths	1 profile wk^{-1}
Solar Radiation		
Global irradiance	Eppley pyranometers with Q, OG1, and RG8 filters*	Continuous
Direct irradiance	Two Eppley pyrheliometers with Q filter*	Continuous
	Eppley pyrheliometer with Q, OG1, RG2, and RG8 filters*	3 day^{-1}
	Eppley/Kendall active-cavity radiometer*	1 mo^{-1}
Diffuse irradiance	Eppley pyrgeometer with shading disk and Q filter*	Continuous
UV solar radiation	Yankee Environmental UVB pyranometers (280-320 nm)*	Continuous
Turbidity	J-202 and J-314 sunphotometers with 380-, 500-, 778-, 862-nm narrowband filters	3 day^{-1}, weekdays
	Precision filter radiometer (368, 412, 500, 862 nm)*	Continuous
Column water vapor	Two-wavelength tracking sunphotometer: 860, 940 nm (two instruments)*	Continuous
Terrestrial IR Radiation	Precision infrared radiometer, pyrgeometer*	Continuous
Solar, UV Index	Davis 6160 (began 10/03)	Continuous
Meteorology		
Air temperature	Aspirated thermistor, 2-, 9-, 37-m heights*	Continuous
	Max-Min thermometers, 2.5m height	1 day^{-1}, weekdays
Air temperature (30-70 km)	Lidar	1 profile wk^{-1}
Temperature gradient	Aspirated thermistors, 2-, 9-, 37-m heights*	Continuous
Dewpoint temperature	Dewpoint hygrometer, 2-m height*	Continuous
Relative humidity	TSL, 2-m height*	Continuous
Pressure	Capacitance transducer*	Continuous
Wind (speed and direction)	10- and 38-m heights*	Continuous
Precipitation	Rain gauge, 20-cm diameter	5 wk^{-1}
	Rain gauge, 20-cm diameter‡	1 wk^{-1}
	Rain gauge, tipping bucket*	Continuous

Table 1.1. Summary of Measurement Programs at MLO in 2002-2003—continued

Program/Measurement	Instrument	Sampling Frequency
Meteorology—continued		
Total precipitable water	Foskett IR hygrometer*	Continuous
Temperature, Wind, Pressure, Precipitation, and Humidity	Davis 6160 (began 10/03)	Continuous
Precipitation Chemistry		
pH	pH meter	1 wk^{-1}
Conductivity	Conductivity bridge	1 wk^{-1}
Cooperative Programs		
CO_2 (SIO)	Applied Physics IR analyzer*	Continuous
CO_2, ^{13}C, N_2O (SIO)	5-L evacuated glass flasks§	1 pair wk^{-1}
CO_2, CO, CH_4, $^{13}C/^{12}C$ (CSIRO)	Pressurized glass flask sample	3 pair mo^{-1}
O_2 analyses (SIO)	5-L glass flasks through tower line and pump unit§	3 $(2\ mo)^{-1}$
Total suspended particulates (DOE)	High-volume sampler (ended 2/03)	Continuous (1 filter wk^{-1})
Ultraviolet radiation (CSU and USDA)	Multi-wavelength radiometer (direct, diffuse, shadow band)	Continuous
Radionuclide deposition (DOE)	Ion-exchange column	Quarterly sample
Aerosol chemistry (Univ. of Calif., Davis)	Programmed filter sampler	Integrated 3-day sample, 1 continuous and 1 downslope sample $(4\ days)^{-1}$
Halides (EPA National Exposure Research Laboratory (NERL)	Sequential Fine Particle Sampler URG 2000-01J (began 05/03)	1 upslope/week and 1 downslope/week
Hg°, Hg^{+2}, Hg^p (EPA National Exposure Research Laboratory (NERL)	Tekran 2537A, 1130 and 1135p	Continuous
Particulate 2.5-10 µm (EPA NERL)	Dichotomous Partisol-Plus model 2025	1 downslope sample wk^{-1}
Sulfate, nitrate, aerosols (Univ. of Hawaii)	Filter system	Daily, 2000-0600 LST
Radon (ANSTO)	Aerosol scavenging of Rn daughters; two-filter system*	Continuous; integrated 30-min samples
AERONET sunphotometers (NASA Goddard)	Automated solar-powered sunphotometers	Continuous
Global Positioning System (GPS) Test Bed (FAA and Stanford University)	GPS-derived column water vapor profiles	Continuous
Earthquakes (HVO-USGS Menlo Park)	Seismometer	Continuous
CO isotopes (SUNY)	1000 psi cylinder	1 $(2\ wk)^{-1}$
Cosmic dust (CALTECH)	Magnetic collector (ended 10/03)	1 $(2\ wk)^{-1}$
Volcanic activity (HVO)	Seismic and expansion instrument in 113-m-deep well	Continuous
Network for the Detection of Stratospheric Change (NDSC)		
Ultraviolet radiation (NOAA and NIWA)	UV spectroradiometer (285-450 nm), 0.8-nm resolution*	Continuous
Stratospheric O_3 profiles, 20-66 km (Univ. of Mass., Amherst)	Millitech Corp., 110.8-GHz microwave ozone spectroscopy	3 profiles h^{-1}
Stratospheric water vapor profiles, 40-80 km, 10-15 km resolution (NRL)	Millimeterwave spectrometer	Continuous
Stratospheric O_3 profiles (15-55 km), temperature (20-75 km), aerosol profiles (15-40 km) (JPL)	UV lidar*	3-4 profiles wk^{-1}
NO_2 (NIWA and NOAA)	Slant column NO_2 spectrometer	Continuous, daytime
BrO (NIWA and NOAA)	Column BrO spectrometer	Continuous, daytime
Column O_3, UVB (MSC, Canada)	Two Brewer spectrophotometers	Daily
Solar spectra (Univ. of Denver)	FTIR spectrometer, automated*	5 days wk^{-1}

All instruments are at MLO unless indicated.
*Data from this instrument recorded and processed by microcomputers.
†Kumukahi only.
‡Kulani Mauka.
§MLO and Kumukahi.
**7-wavelength aethalometer relocated to Boulder CMDL for absorption intercomparison study 4/2002.

Aerosols

The aerosols system operated without any problems during 2002 and 2003. A new computer, nephelometer, and a new particle soot absorption photometer (PSAP) were installed in 2003.

Aerosol absorption. The spectrum aethalometer was sent to Boulder for calibration on 29 April 2002. After it is used in a black carbon measurement instrument intercomparison study, it will be returned to MLO in early 2004.

Stratospheric and tropospheric aerosols and water vapor. Weekly vertical profile observations continued with the Nd:YAG lidar throughout 2002 and 2003. The stratospheric aerosol background period continued, but there were several small peaks in the aerosol layer that indicated there were some volcanic eruptions. The volcanic aerosol peaks persisted for only a few weeks at a time and were never more than two or three times the background level. Raman water vapor measurements continued with the new telescope and detectors. Seventeen validation measurements, in support of the Atmospheric Infrared Sounder (AIRS) instrument on the National Aeronautical and Space Administration (NASA)/AQUA satellite, were performed for the 0200 LST overpasses.

There was a major failure of the Nd:YAG laser that required a service call from a mainland-based technician. The replacement of the Q-switch necessitated a realignment of the laser cavity. The manufacturer of the original laser no longer supports the equipment but was able to recommend an independent technician to do the repairs.

Initial measurements, using a new technique for measuring boundary layer aerosols, were obtained by imaging the laser beam from a distance (about 200 m) with a cooled digital camera and a wide-angle lens. This method provides high resolution aerosol data all the way to the surface that can be compared to measurements from the MLO in situ nephelometer.

Solar Radiation

The normal incident pyrheliometers (NIP) data signal occasionally picked up noise following a rain. The NIP grounding wires were replaced and configured into a single-point electrical ground system in 2002 that alleviated the noise problem.

Three global pyranometers along with NIP 1 and Diffuse 1 were replaced in 2002. The diffuse IR pyrgeometer was replaced in 2003.

The SP01 sunphotometer was in operation at MLO from April to June 2002. The SP02 sunphotometers were in operation from October to November 2002 and from March to June 2003.

An active cavity radiometer was received from Boulder in June 2002. The instrument had performed intercomparisons in Boulder since May 2001. Turbidity box J202 was refurbished in June 2002, and Turbidity box J314 was sent to Boulder for refurbishing in August 2002.

The shadowband worm gear drive for Diffuse 1 was realigned in February 2002. The solar dome azimuth motor mount was fixed in December 2002, and a spring shock adjustment was added to the mount. The HP data acquisition unit, used for the solar dome instruments, was replaced with a Campbell data logger in April 2003. The solar spar declination motor drive shaft was replaced in October 2003.

Meteorology

A computer-based meteorological system measures station pressure, temperatures at the 2-, 9-, and 37-m levels, dew point temperature at the 2-m level, and wind speeds and directions at the 8.5-, 10-, and 38-m levels of the MLO Observation Tower. This system continued to operate with high reliability in 2002 and 2003. Precipitation at the station is measured with a tipping bucket rain gauge.

A new meteorology system called “Webmet” was set up to provide current information though the MLO Web site. It is primarily designed to provide real-time data in an easy-to-read graphical format. The meteorological information provides air pressure, precipitation, outside temperature, dew point, humidity, wind speed, and wind direction. The system also measures the temperature, dew point, and humidity inside of the Keeling building. In addition to the meteorological information displayed on the Web, the system provides solar information and calculates the current UV index, the time of sunrise and sunset, and phases of the moon. The link to the “Webmet” site is: http://www.mlo.noaa.gov/LiveData/mlomet/webmet.htm.

Precipitation Chemistry

The MLO modified program of precipitation chemistry collection and analyses continued throughout 2002 and 2003 within the basic MLO operational routine. This program consists of a weekly integrated precipitation sample collected from the Hilo NWS station and precipitation event samples collected at MLO. Analyses of these samples for pH and conductivity are undertaken in the MLO Hilo laboratory.

Cooperative Programs

The MLO Cooperative programs are listed in Table 1.1. New programs and changes not discussed in the following NDSC section are presented here.

The Colorado State University (CSU)/U.S. Department of Agriculture (USDA) UVB-1 instrument was replaced in July 2003 because water leaked into the instrument.

In May 2003 the first run started on the U.S. Environmental Protection Agency (EPA) Sequential Fine Particle Sampler (SFPS). The denuders and filter packs are sampled weekly. The programming is being tested. The final consideration for upslope and downslope winds and days of exposure is to be determined at a later date. The URG sampler malfunctioned until the proper memory chips and replacement parts were received. The precursor to this program was the VAPS manual sampler that ran in late 2001 and early 2002.

The University of Hawaii nitrate filter program installed a filter in September 2002 for the exhaust of their carbon vane vacuum pump. The filter traps any black carbon released by the pump that might affect other sampling programs.

The Australian Nuclear Science and Technology Organization (ANSTO) processed the MLO radon data from 1997 to 2002, and the data is archived on the MLO FTP server. Forty feet (12 m) of PVC intake pipe, the power supply, and the external tank blower were replaced in the last 2-years. A new radon tank and sensor were installed in December 2003.

The NASA Aerosol Robotics Network (AERONE) calibrated several new sensors in April 2003. They also installed an additional robot assembly used to calibrate the new sensors.

The CO isotope State University of New York at Stonybrook (SUNY) sampling program restarted in August 2003 after a hiatus since October 2001. The sampler uses a compressor to fill an air cylinder to 1000 psi. After an initial sampling period of every week, the frequency was changed to every other week.

The California Institute of Technology (CALTECH) cosmic dust collector continued to operate until October 2003.

Network for the Detection of Stratospheric Change (NDSC)

All NDSC instruments from previous years continued observations. The NOAA lidar, ozonesonde, and Dobson operations, which are also part of the MLO NDSC facility, are described in other sections of this report.

UV/VIS spectroradiometer. The UV instrument began operation in the MLO NDSC building in November 1997. The UV spectroradiometer uses a double monochromator grating spectrometer to measure the UV spectrum between 285 and 450 nm with a resolution of 0.8 nm. Measurements are taken at 5° solar zenith angle intervals throughout the day. The instrument is calibrated weekly using a mercury lamp and a 45-W quartz lamp. An absolute-standard 1000 W FEL lamp calibration is performed twice each year. A power outage in June 2003 caused a wavelength misalignment that was fixed by the installation of a new data file from the National Institute of Water and Atmospheric Research (NIWA).

Microwave ozone and water vapor spectroscopy systems. The University of Massachusetts microwave instrument measures the vertical profile of ozone from 20 to 70 km with a vertical resolution of 10 km or less up to 40 km, degrading to 15 km at 64 km. The ozone altitude distribution is retrieved from the details of the pressure-broadened line shape. The Naval Research Laboratory (NRL) operates a similar water vapor system to measure vertical profiles typically from 40 to 80 km. Both systems received the usual maintenance and continued operations in 2002 and 2003.

UV lidar. The NASA Jet Propulsion Laboratory (JPL) ozone lidar continued in operation averaging two-to-three observations per week. Additional campaigns were also performed involving all-night operations for 2 weeks. The large excimer laser (oscillator and amplifier) was replaced with a new model. The new laser is smaller, and, because it does not sit on the floor like the previous unit, additional aluminum optical rails were needed to support it. These modifications opened up additional space for easier operation and maintenance of the lidar.

NO_2, BrO spectrometers. Since 9 July 1996, stratospheric nitrogen dioxide (NO_2) has been measured at MLO using the twilight zenith technique with a NIWA UV/VIS spectrometer. Two additional spectrometers were added in December 1999 for column measurements of NO_2 and BrO. The BrO spectrometer measures the stratospheric bromine monoxide, an important species in current attempts to model future nonpolar ozone trends. The instruments are operated over the Internet by NIWA in Lauder, New Zealand.

Brewer spectrophotometers. A single monochromator Brewer instrument was installed by the Meteorological Service of Canada (MSC) at MLO and began routine measurements of O_3 and UV-B radiation on 24 March 1997. A second instrument was added in November 1997. The measurements are supplemented by all-sky images that are recorded every 10 minutes to assist in the analysis of the UVB data. Overviews of the automatic operation of the instrument and data retrievals are carried out remotely from Toronto over the Internet. The data are archived at the World Ozone and Ultraviolet Data Centre (WOUDC) in Toronto. Up-to-date preliminary data are also available over the Internet from MSC. Publication of some new results is planned after a thorough analysis of a longer data record is complete. Annual maintenance and calibration checks along with software upgrades to both units, in addition to other instrumentation calibrations, were carried out in March and November 2002. (The laptop calibration computer was taken back to MSC in 2002.) On April 2002 unit 119's double micrometer top was restored to its original configuration after being reworked with temporary bolts and wires the month before. Maintenance on these units includes work on the zenith and azimuth gear drives, realignment of the LED on the master gear, and adjustments and repairs to the micrometer section.

Solar Fourier transform infrared (FTIR) spectrometer. The University of Denver FTIR spectrometer routinely monitors HCl, HNO_3, O_3, N_2O, F-22, HF, CH_4, NO, HCN, CO, C_2H_2, and C_2H_6. Because of the automatic nature of the instrument, the program is able to look at diurnal variations in the species. Data are not collected on Sundays or Monday mornings unless special operators are on site to add liquid nitrogen to the instrument. The system was down for major instrument and computer repairs from 28 January 2002 to 6 April 2003.

1.2. Barrow Observatory

1.2.1. Operations

January 2003 marked the 30^{th} year of continuous operation for the Barrow Observatory (BRW) which opened its doors in January 1973 with a total of 13 internal projects and 2 cooperative programs. In the *NOAA Geophysical Monitoring for the Climatic Change Summary Report No. 2* [*Miller*, 1973, p. 17], the ambient CO_2 mixing ratio ranged from a low of 317 ppm to a high of 326 ppm, while in the *Climate Monitoring and Diagnostics Laboratory (CMDL) Summary Report No. 26* [*King et al*, 2002, pp. 29 and 33] the mean CO_2 mixing ratio for 2001 was 372 ppm. The *CMDL Summary Report No. 26* also lists 23 internal projects and 21 cooperative projects with 6 more projects approved for 2002. By the end of 2003 the project count, including several completed projects, is 22 CMDL internal projects and 21 cooperative projects.

In January 2002 there was a change of personnel. The technician left for school and a replacement arrived in mid-February 2002. In July 2003 that technician left for a position in Boulder and the latest replacement arrived in August 2003. The station chief, with over 19 years of service at BRW, remains the same.

Facility improvements during the past 2 years at BRW included high-quality shelving in the garage to keep boxes and equipment from getting wet when the snowmelt from the trucks floods the floor. A contract is out for bid for a drip pan to be built to catch runoff from the trucks. The new, heated garage has greatly improved winter working conditions along with staff productivity and safety at the Barrow Observatory.

Both General Services Administration (GSA) vehicles, a 1997 Ford F-250 and a 2000 Chevrolet 3500 Crew Cab, continue to run well. Minor maintenance, such as changing the oil, was performed by station personnel.

In 2003 a Bobcat T190 compact track loader (Figure 1.1) was purchased to help move pallets of compressed gas cylinders. It is also used for minor road repairs during the summer, and during the winter it is used to keep the road cleared of snow with the aid of a snow blower attachment.

Station computers were upgraded and three new computers were purchased. All computers are now the same make and model which simplifies software updates and modifications.

In 2002-2003 over 200 visitors signed the BRW guest book including several documentary film crews, a large number of visiting scientists, and an appreciable number of students. Also, the number of user days for cooperative programs at the station greatly increased. Visiting researchers are no longer in BRW for just the spring/summer; they are present every month collecting data from the automated systems and performing maintenance on the continuous data collection systems.

In January 2003 the station chief traveled to Nome, Alaska, to train several Russian high school students from two different villages across the Bering Strait on the correct procedures for collecting snow samples for mercury analysis. The mercury analysis program is funded by the U.S. Environmental Protection Agency and the U.S. State Department through a grant to the Barrow Arctic Science Consortium (BASC).

1.2.2. PROGRAMS

Table 1.2 lists programs for 2002-2003 at BRW as well as cooperative programs that operated in 2002-2003. Highlights of the programs are as follows:

Gases

Carbon dioxide. During the spring and summer of 2003 the CO_2 Siemens Ultramat 5-E system was replaced by a LiCor LI-6251. After some start-up problems, the system appears to be working well. The upgrade also consisted of an improved system for sample collection from the analyzer into the flasks as well as a change in the air delivery plumbing. The plumbing modification was in response to a newer schedule for hourly and weekly calibrations due to a reduction in the number of calibration gasses needed to run the system.

Figure 1.1. BRW Bobcat T-190 compact track loader.

The HP computer-based data acquisition system was replaced with a UNIX-based system. The newer Data Acquisition System (DAS) also collects data for the CO and CH_4 programs. The system ran well.

Flask samples. Flask samples were collected as scheduled. There were no major problems with the flask program. Isotopic composition measurements of CO_2 continue and data from this program can be found elsewhere in this report.

Methane. The HP-6890 gas chromatograph continues to run with very few problems. Data shows a clearly defined frequency with high values occurring in the winter months and lower values occurring in the summer.

Surface ozone. A Thermo Environmental Instruments (TEI) 49C is now run in conjunction with the station Dasibi. The Dasibi ozone instrument is aging and parts are becoming hard to find. Both instruments appear to be giving similar results with no problems noted. The original TEI was on loan from the EPA and was replaced with a newer model in July 2003 by personnel from Boulder.

Total column ozone. The Dobson ran well the entire period with no major problems. Values as high as 400 Dobson units (DU) are seen in spring, but by late summer the values can fall as low as 290 DU. Ozone data collection is not possible during the winter months because of a lack of sunlight. The Dobson 91 was sent to Boulder in the fall of 2003 for calibration and maintenance since regular calibrations are performed to maintain the instrument.

Carbon monoxide. A Trace Analytical gas chromatograph has been the station instrument since 1991 and continues to run with minimal maintenance. The UV lamp replacement was the only maintenance required.

Halocarbons and other atmospheric trace species. The Chromatograph for Atmospheric Trace Species (CATS) ran well with only minor problems. Twelve different species are measured in situ on the CATS system. The most notable problem was a water trap that caused bad traces on one of the four channels. The trap was replaced and the instrument ran properly. A flash heater for the cryo-focusing trap was replaced when the old one burned out.

Halocarbon flask samples were collected on a routine schedule to provide a comparison for in situ instrument performance as well as to give Boulder the ability to analyze several chemical species that BRW is not equipped to handle.

Aerosols

Arctic haze continues to dominate the springtime aerosol signal at BRW. Aerosol concentrations increase over the winter months and peak in the spring. Then they rapidly decrease when leads open in the late spring to early summer. The resulting clouds scavenge the aerosols from Eurasia. The aerosol monitoring instruments ran well for the entire period with only minor problems encountered. The aerosol data was collected continuously by the system computer and was transferred daily to Boulder for analysis. Personnel from Boulder performed the annual maintenance, the system calibrations, and the software upgrades on the aerosol equipment.

Table 1.2. Summary of Measurement Programs at BRW in 2002-2003

Program/Measurement	Instrument	Sampling Frequency
Gases		
CO_2	Siemens Ultramat 5-E analyzer/Li-COR 6251	Continuous
	3-L evacuated glass flasks (ended 2003)	1 pair wk^{-1}
	2.5-L glass flasks, through analyzer	1 pair wk^{-1}
CO_2, CH_4, CO, $^{13}C/^{12}C$, $^{18}O/^{16}O$ of CO_2, H_2, N_2O, SF_6, and ^{13}C of CH_4	2.5-L glass flasks, MAKS pump unit	1 pair wk^{-1}
CH_4	HP6890 automated GC	1 sample (12 min)$^{-1}$
Surface O_3	Dasibi ozone meter	Continuous
	TEI ozone meter	Continuous
Total O_3	Dobson spectrophotometer no. 91	3 day^{-1}
CO	Trace Analytical GC	1 sample (6 min)$^{-1}$
CFC-11, CFC-12, CFC-113, CFC-114/CFC-114a, HCFC-21, HCFC-22, HCFC-124, HCFC-141b, HCFC-142b, HFC-134a, HFC-152a, H-1211, H-1301, CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4, CH_3CCl_3, C_2Cl_4, CH_3Br, CH_2Br_2, $CHBr_3$, CH_3I, N_2O, SF_6, COS, C_6H_6	850-mL, 2.5-L, or 3-L stainless-steel flasks	1 pair wk^{-1}
CFC-11, CFC-12, CFC-113, HCFC-22, HCFC-142b, H-1211, H-1301, CH_3Cl, $CHCl_3$, CCl_4, CH_3CCl_3, CH_3Br, N_2O, SF_6, COS	Automated CATS GC	1 sample h^{-1}
Aerosols		
Condensation nuclei	Pollack CNC (removed 2/2002)	1 day^{-1}
	TSI CNC	Continuous
Optical properties	Three-wavelength nephelometer	Continuous
Aerosol light absorption (black carbon)	Aethalometer replaced with Radiance Research PSAP in 2/2002	Continuous
Solar Radiation		
Global irradiance	Eppley pyranometers with Q and RG8 filters	Continuous
Direct irradiance	Tracking pyrheliometer with Q filter	Continuous
	Eppley pyrheliometer with Q, OG1, RG2, and RG8 filters (manual filter-wheel NIP)	3 day^{-1},weather permitting
Diffuse Irradiance	Eppley pyranometers with shading disk	Continuous
Albedo	Eppley pyranometer Q	Continuous
Ultraviolet B irradiance	BSI GUV radiometer	Continuous
All Sky Camera	Yankee Environmental Systems, Inc. TSI all-sky camera	1 $minute^{-1}$
Terrestrial (IR) Radiation		
Upwelling and downwelling	Eppley pyrgeometers	Continuous
Meteorology		
Air temperature	Logan platinum resistance probe	Continuous
Dewpoint temperature	TSL dew-point hygrothermometer	Continuous
Pressure	Setra Capacitive pressure transducer	Continuous
	Mercurial barometer	1 wk^{-1}
Wind (speed and direction)	R.M. Young wind monitor	Continuous
Cooperative Programs		
Total surface particulates (DOE)	High-volume sampler (1 filter wk^{-1})	Continuous
Precipitation gauge (USDA)	Nipher shield, Alter shield, two buckets	1 mo^{-1}
Magnetic fields (USGS)	Three-component fluxgate magnetometer and total field proton magnetometer	Continuous
	Declination/inclination magnetometer sample	4 pair wk^{-1}
CO_2, ^{13}C, N_2O (SIO)	5-L evacuated glass flasks	1 pair wk^{-1}
CH_4 (Univ. of Calif., Irvine)	Stainless-steel flasks	1 pair (3 mo)$^{-1}$
C_{14} in air (Univ. of Calif., Irvine)	5-L evacuated flasks	1 pair (2 wk)$^{-1}$
O_2 in air (Princeton)	3-L glass flasks	1 pair wk^{-1}
CO_2 flux (San Diego State Univ.)	CO_2 and H_2O infrared gas analyzer and sonic anemometer	Continuous, check site 1 wk^{-1}
Magnetic fields (NAVSWC)	He sensors	Continuous
Magnetic micropulsations (Univ. of Tokyo)	Magnetometer and cassette recorder	1 tape (3 wk)$^{-1}$
UV (NSF)	UV spectrometer	1 scan (0.5 h)$^{-1}$
Thaw depth in permafrost (SUNY)	Temperature probe	Continuous

Table 1.2. Summary of Measurement Programs at BRW in 2002-2003—continued

Program/Measurement	Instrument	Sampling Frequency
Cooperative Programs —continued		
Atmospheric mercury (NOAA/ARL)	Mercury vapor monitors	Continuous
POES satellite transmission downlink (NESDIS)	3-m dish and receiver	Per satellite crossing
POES satellite transmission uplink (under construction) (NESDIS)	4-m dish and receiver	Per satellite crossing
Heavy metals (Univ. of Alaska, Fairbanks)	Paper filters	Continuous
Persistent organic pollutants (Battelle-Northwest Labs.)	High-volume pump (ended 10/2003)	Continuous
SuomiNet GPS meteorology station (Univ. of Alaska, Fairbanks)	GPS water vapor measuring station	Continuous
Climate reference network station (NESDIS)	Temperature, wind, precipitation sensors	Continuous
Aerosol chemistry (PMEL)	Major ions, mass	1 day^{-1}
Particle number chemistry (PMEL)	Aerosol Filters/Ion Chromatography	1 day^{-1}

Solar Radiation

The old albedo rack was taken out of service in the fall of 2003 after more than a year of intercomparison with a newer rack installed in 2001. The new albedo rack produces good data with a wider field of view than its predecessor. The new rack needs to have additional guy lines installed to better support it during windstorms. The installation of the guy lines will be done as soon as possible but is currently stalled by a new Bureau of Land Management (BLM) requirement. The requirement states that before any ground disturbance can take place on the CMDL property, there must be an archeological assessment completed by BLM personnel. Also, finding an auger in Barrow, suitable for drilling in permafrost and is relatively portable, is a problem. Sea-ice augers are common in Barrow, but small augers for tundra/permafrost drilling do not exist. BRW may have to purchase or rent one from Fairbanks or Anchorage and have it flown in.

Meteorology

There were no significant problems with the meteorology system during 2002-2003. Manual comparison observations were taken two or three times per week and any changes in weather were noted. All sensors were calibrated and adjusted as needed.

Cooperative Programs

There were several changes of note this year in the cooperative programs. The Persistent Organic Pollutants (POPs) project ended. This was a project with Battelle-Northwest Laboratory funded by the NOAA Study of Environmental Arctic Change (SEARCH) program. The data collected over the 2 years of the project looked good. This project may be restarted in the future.

A program with the University of Alaska, Fairbanks, also measured POPs and a project that measured heavy metals was completed in the fall of 2003.

The NOAA National Environmental Satellite, Data, and Information (NESDIS) program is expanding with the addition of a second polar dome and a 4-m dish in early 2004. By the end of 2003, a platform was completed and ready for the installation of the new transmit dish that will control polar orbiting satellites. The data from the earlier installed 3-m "receive only" dish (Figure 1.2) surpassed all expectations as to the amount and quality of data that can be downloaded to the BRW site. These dishes are located north of the main observatory building, out of the clean-air sector, and situated to prevent snow drifts on the road.

Figure 1.2. NOAA NESDIS platform and antenna dome for downloading polar orbiting satellite data at the Barrow Baseline Observatory.

1.3. Samoa Observatory

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M. Cunningham, and D. Simon

1.3.1. Operations

American Samoa is located in the middle of the South Pacific, about midway between Hawaii and New Zealand. It is characterized by year-round warmth and humidity, lush green mountains, and the strong Samoan culture. The observatory is situated on the eastern most point of Tutuila Island at Cape Matatula.

The SMO electronics engineer was replaced in January 2003 and the station chief was replaced in March 2003 and again in August 2003.

One of the most interesting items was the damage and ongoing recovery from the category 4 cyclone (Heta) with peak winds of 305.77 km/h that hit Samoa 4 January 2004. The station and staff housing were severely damaged in the cyclone and the observatory electric generator was destroyed. The air-sample pump house, located 37.19 m above sea level, was inundated by waves and all instruments in the building were washed away or destroyed when the door gave way. Sea swells of 18.29 m were measured off the Samoan coast (Figure 1.3). The Dobson ozone spectrophotometer dome was bent out of shape and the water entering the dome destroyed the Dobson control computer. The bottom four stories of the stairs down to the point were washed away. This saved a contractor the bother of ripping them out since the 12-story tall stairs that lead to the point were scheduled to be replaced beginning in late January 2004. The new stairway will be built with treated lumber and new concrete pedestals will be installed. The new design reduces the steepness of the more dangerous sections of the former staircase.

During the cyclone most externally mounted sensors and instruments at the station were damaged or bent out of shape. The observatory is expected to be back in full operation by June 2004. The two staff houses in Tafuna will need new roofs. Leaking caused some damage to the interiors before the staff was able to cover the roofs in plastic sheeting as a temporary fix. Repair costs for the station and houses are expected to exceed $250,000 (Figure 1.4).

In 2004 an aerosol lidar will be installed at the NWS facility at the Pago Pago Airport and will be operated by observatory personnel. NWS moved to a new facility at the airport in November and CMDL will occupy one of their former buildings. The new building is designated for lidar operations and for ozonesonde preparation. At present the ozonesondes are prepared at the observatory and driven 41.84 km to the airport for launching.

The observatory played host to 20 participants at the Joint 25th Meeting of Advanced Global Atmospheric Gases Experiment (AGAGE) scientists and special meeting of CMDL scientists 7-10 May 2002. The observatory hosted many other visitors, of particular note was a delegation from the Samoa Department of Lands in the independent country of Western Samoa who visited the CMDL observatory seeking information on how to develop a UV radiation and ozone observatory of their own. The observatory hosted a number of school groups including a group that came to watch an ozonesonde balloon launch.

The new Samoa station electronics engineer came to SMO in January 2003 with a wealth of computer networking experience. Early in his tenure he instituted a process for backing up all data systems on the observatory network through the creation of a bootable "Ghost" restore CD system. He also discovered a problem with the station electrical ground that feeds the network meteorological solar equipment. The ground measured 55 volts of alternating current (VAC). A new ground was installed and the problem was remedied. In June 2002 the first good Internet connection to SMO was officially established. In July firewalls were in place, and in August the computer network was fully operational.

Maintenance issues continue to be addressed at the observatory. The cold-water line to the observatory was found to be corroded and leaking. It was replaced with PVC piping outside the building and a new line was installed inside. The cistern water

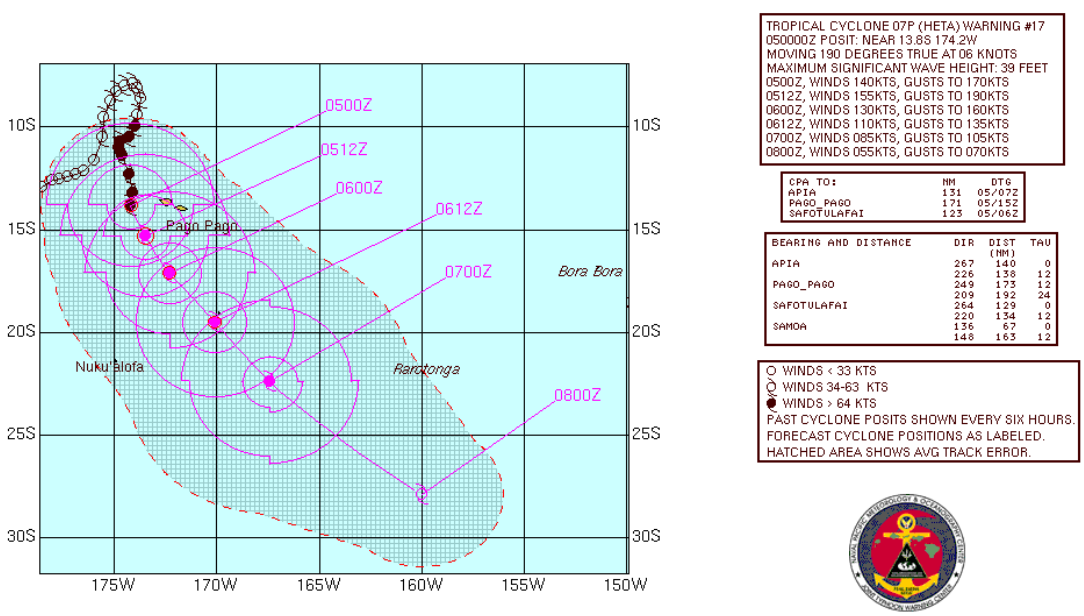

Figure 1.3. On 4 January 2004 the observatory was swept by tropical cyclone Heta. Note that at 0517Z the winds were gusting to190 knots (218 mph) just west of Samoa. This was about the time waves were reaching the Samoa Observatory pump building located 37.19 m above sea level.

Figure 1.4. The next house down from the two CMDL staff houses in Tafuna. The occupants were sheltering in the bedroom when the roof was blown off above them. The CMDL houses fared better.

system was pumped dry, cleaned, and inspected. Also, the septic tank was pumped and problems with the connection to the dry well were repaired. Prior to the cyclone, significant amounts of vegetation were cleared from around the stairway in preparation for the upcoming stairway project. The cyclone itself removed additional vegetation to produce a well-cleared path for the reconstruction of the stairway. The exterior concrete stairway to the solar radiation platforms and Dobson dome on the observatory roof was repainted with anti-slip material to eliminate slip hazard during and after rains. The observatory rooftop surface was cleaned and resealed with deck paint. The interior of the main laboratory, technician's room, and supply room were repainted. Wooden support pillars were stripped, sanded, and varnished. The Hudson building and pump house were repainted prior to the cyclone and may require additional repainting after building repairs are complete. In the Hudson building, secure cylinder areas were created and the leaking roof was replaced prior to the cyclone. The Dobson dome was cleared of rust and repainted. Extensive repairs to the generator were made in the weeks prior to the cyclone. Unfortunately, the cyclone destroyed the 90-KVA generator when water was forced into the carburetor that subsequently caused the engine to literally explode. At wind speeds in excess of 257 km, the rain entered the building on a horizontal plane then rose over 0.5 m to get into the carburetor. The generator was operating during the storm because the power on the Island was off. The power remained off for several weeks.

In 2001 the kitchen, bath, laundry, utility, and living room in the technician's house were renovated. In 2003 the back half of the same house was renovated just in time to be damaged by the cyclone. In the last renovation, two larger rooms were created from two bedrooms and a study to allow better air flow. The house was reassigned to the station chief and in future reports will be referred to as the station-chief's house.

The main observatory building needed some major repairs to combat concrete spalling (concrete breaking down) prior to the cyclone. An evaluation of the concrete spalling was conducted in March 2002 by a company on the island and submitted to CMDL. Plans are in development to build a new roof on the station and to repair the spalling concrete. Funding for these major repairs has not yet been secured.

1.3.2. Programs

Table 1.3 summarizes the programs at SMO for 2002-2003. Operational highlights follow:

Gases

Carbon dioxide. In situ monitoring and Airkit samples continued without interruption during the 2002-2003 reporting period.

Carbon cycle greenhouse gases. A 10-m tall pivoted mast is located on a point of land jutting out from the cape where the observatory is situated. This mast carries the sampling line for CCGG's CO_2 instrument. The metal supports for this mast were replaced in May 2002 because of excessive rust. The rusted ends of the CO_2 sampling lines were removed since they were thought to be causing quality problems for the hydrogen measurements. A

Table 1.3. Summary of Measurement Programs at SMO in 2002-2003

Program/Measurement	Instrument	Sampling Frequency
Gases		
CO_2	Siemens Ultramat-5E analyzer	Continuous
CO_2, CH_4, CO, $^{13}C/^{12}C$, $^{18}O/^{16}O$ of CO_2,	2.5-L glass flasks, AIRKIT	1 pair wk^{-1}
H_2, N_2O, SF_6, and ^{13}C of CH_4	2.5-L glass flasks, through analyzer	1 pair wk^{-1}
Surface O_3	TEI UV photometric ozone analyzer	Continuous
Total O_3	Dobson spectrophotometer no. 42	3 day^{-1}
O_3 profiles	Balloon borne ECC sonde	1 wk^{-1}
CFC-11, CFC-12, CFC-113,	2.5-L glass flasks, AIRKIT	2 pairs mo^{-1}
CFC-114/CFC-114a, HCFC-21, HCFC-22, HCFC-124, HCFC-141b, HCFC-142b, HFC-134a, HFC-152a, H-1211, H-1301, CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4, CH_3CCl_3, C_2Cl_4, CH_3Br, CH_2Br_2, $CHBr_3$, CH_3I, N_2O, SF_6, COS, C_6H_6	850-mL, 2.5-L, or 3.0-L stainless-steel flasks	1 pair wk^{-1}
CFC-11, CFC-12, CFC-113, HCFC-22, HCFC-142b, H-1211, H-1301, CH_3Cl, $CHCl_3$, CCl_4, CH_3CCl_3, CH_3Br, N_2O, SF_6, COS	CATS four-channel automated GC	1 sample h^{-1}
Aerosols		
Condensation nuclei	Pollak CNC (terminated 11/03)	1 day^{-1}
Solar Radiation		
Global irradiance	Eppley pyranometers with Q and RG8 filters	Continuous
Direct irradiance	Eppley pyrheliometer with Q filter	Continuous
	Eppley pyrheliometer with Q, OG1, RG2, and RG8 filters (manual filter-wheel NIP)	3 day^{-1}, weather permitting
Diffuse irradiance	Eppley pyranometers with shading disk and Q filter	Continuous
Terrestrial (IR) Radiation		
Downwelling	Eppley pyrgeometer	Continuous
Meteorology		
Air temperature	Thermistors (2)	Continuous
Dewpoint temperature	TSL hygrothermometer	Continuous
Pressure	Capacitance transducer	Continuous
	Mercurial barometer	1 wk^{-1}
Wind (speed and direction)	R.M. Young windbird	Continuous
Precipitation	Rain gauge, tipping bucket	Continuous
	Rain gauge, plastic bulk	1 day^{-1}
Cooperative Programs		
CO_2, ^{13}C, N_2O (SIO)	5-L evacuated glass flasks	1 trio wk^{-1}
CO_2, O_2, N_2 (SIO)	5-L glass flasks	2 trios mo^{-1}
CH_4, N_2O, $CHCl_3$, CFC-11, CFC-12, CFC-113, CCl_4, CH_3CCl_3 (NASA-AGAGE)	HP5890 Series II 3 channel gas chromatograph	3 h^{-1}
Total suspended particulates (DOE/USDHS)	High-volume filter sampler	Continuous (1 filter wk^{-1})
Global deposition sampling (DOE/USDHS)	Ion-exchange collector	Continuous (4 filter yr^{-1})
Total suspended particulates (SEASPAN)	High-volume filter sampler	Continuous (1 filter wk^{-1})
Light hydrocarbons (Univ. of California, Irvine)	1-L evacuated stainless steel flasks	3-4 flasks qtr^{-1}
O_2 (Princeton Univ.)	2.5-L glass flasks	1 pair wk^{-1}
H_2O budget (USGS, Samoa EPA)*	Evapotranspiration pan	Continuous
CO/C^{114} (SUNY)	Air-sampling compressor	Discretes

SIO, Scripps Institution of Oceanography.
DOE/USDHS, DOE under Department of Homeland Security (USDHS) as of 1 March 2003.
*USGS, Samoa EPA project completed and equipment removed June 2002.

marked improvement in CO_2 data stability was observed after moving the CO_2 system into the only continuously climate-controlled room at the observatory.

Surface ozone. In situ monitoring with the Thermo Environmental Instrument (TEI) UV photometric ozone analyzer operated continuously throughout the reporting period. Two equipment problems with a chart printer and a pump diaphragm were not severe enough to stop the instrument or to take the system off line for an extended period.

Total ozone. The Dobson spectrophotometer continued to operate reliably during the normal reporting period, although it was out of service for about 6 weeks following the 4 January 2004 cyclone.

Ozonesonde balloons. Weekly ozonesonde flights continued during this reporting period using the NWS balloon inflation facility at the Tafuna airport. NWS constructed a new balloon inflation facility and we look forward to using this facility during the next reporting period.

Halocarbons and other atmospheric trace species. The CATS operated continuously during this reporting period.

Aerosols

The only aerosol measuring instrument at Samoa is a Pollak counter. Daily Pollak observations were conducted throughout most of the reporting period, but terminated in November because of equipment failure. A new CN counter was installed in February 2004.

Solar Radiation and Meteorology

The solar radiation and meteorological instruments continued to operate throughout the reporting period.

Cooperative Programs

A complete list of SMO cooperative projects is found in Table 1.3. All programs operated without significant problems during the reporting period. The removal of the joint USGS/ American Samoa Environmental Protection Agency (ASEPA), and the University of Hawaii Ground Water Estimate Project occurred on 4 June 2002. The tower, located close to the observatory, was removed after roughly a year of data acquisition. In January 2002 a cooperative project that samples radionuclide deposition using an ion-exchange collector was restarted for the U.S. Department of Homeland Security. The project was formerly under the U.S. Department of Energy. The instrument is mounted on the roof near the solar instruments. A BAE Systems missile detector system was installed at the observatory beginning 8 March 2002 and operated for 2 weeks in a U.S. Department of Defense project involving ozone detection and related interferences for antiballistic missile defense tests.

The State University of New York at Stonybrook (SUNY) installed a new CO/C^{14} instrument in August 2003. The SUNY sampling system is based on a modified drive-tank compressor. A steel cylinder is filled with air compressed to 900 psi weekly in August-September and December-March. In September-December and March-July samples are biweekly.

The U.S. National Geodetic Survey (NGS) installed high-accuracy reference points at the observatory with a reported accuracy of ±2 cm making SMO a part of the global NGS High Accuracy Reference Network (HARN). A report detailing the location of these benchmarks is available from the station chief and a copy is kept at the station.

1.4. South Pole Observatory

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1.4.1. Operations

The CMDL South Pole Observatory (SPO) is located at the geographic South Pole on the Antarctic plateau at an elevation of 2838 m above sea level. CMDL projects are housed in and around the Atmospheric Research Observatory (ARO) and the Balloon Inflation Facility (BIF), both are National Science Foundation (NSF) facilities for the support of scientific projects related to atmospheric research. The ARO and BIF facilities are part of the NSF Office of Polar Programs (OPP) United States Antarctic Program (USAP). The South Pole Station cargo, personnel travel, housing, building maintenance, and electrical power are all supported by NSF through the contractor, Raytheon Polar Services Company (RPSC). RPSC has been the support contractor since April 2000.

The ARO facility is approximately 500-m grid east-northeast of the new elevated station. This location is generally separated and upwind from station operations. The grid system is used at South Pole Station to define Cartesian coordinates. Grid north (0°/360°) is defined as the line representing the prime meridian or zero line of longitude and is called "north." The 180° line from South Pole is referred to as "south." A Clean Air Sector (CAS) was established and is defined as the area beyond the ARO facility from grid 340° to grid 110°. The prevailing winds at South Pole are from CAS more than 90% of the time.

CAS was established to preserve the unique atmospheric and terrestrial conditions from South Pole Station influences. Except for special circumstances, access to the CAS is prohibited. This includes foot and vehicle traffic. Aircraft activity is limited in CAS, and guidelines for scientific or other activities are under discussion at this time. The pristine nature of CAS is strictly preserved, not just for the current scientific activities, but also for future science at South Pole.

CMDL's stratospheric ozonesonde program is conducted from BIF, at approximately 100-m grid south of the new elevated station. This facility is shared by the RPSC meteorology staff and occasionally by special projects with other research groups. Construction is set to begin in the austral summer 2004 on BIF and the neighboring cryogenic building. Improvements include new doors for the inflation room, upgrades for the heating system, and an enclosed facility for storing helium. The building will be sided to match the new station.

There are two distinct seasons at the South Pole. The busy summer season from late October to mid-February when station population can exceed 240 persons and the quiet winter season where population is reduced to approximately 60 "winterovers" consisting of science, support staff, and construction personnel. The winter population increased from approximately 28 in 1998 to over 60 in the past years because of the increased construction activities with the new elevated station. Once construction is complete, the winter population is expected to return to 30.

Transportation to and from the South Pole station is limited to ski-equipped aircraft. All cargo, personnel, and fuel is flown in by the 109th Airlift Wing of the New York Air National Guard.

During the austral summer, the Air National Guard schedules approximately 300 LC-130 flights to South Pole Station from McMurdo Station. These flights take place from late October to mid-February (station opening to station closing). Other aircraft activities at South Pole station include several De Havilland DH-6 Twin Otter flights, contracted by NSF for special operations, and the occasional non-government flights by private companies providing tourist transport or support for adventurers. On 21 September 2003, coinciding with the South Pole sunrise, the third winter medical evacuation since 1999 was completed by Kenn Borek Air Ltd. of Alberta, Canada, under contract to RPSC using a Twin Otter aircraft. The patient was flown to Punta Arenas, Chile, through the British Antarctic Survey's Rothera Station on Adelaide Island.

Because of the remote location, darkness, and extreme cold winter flights were previously considered far too dangerous to attempt. However, emergency medical evacuations have now taken place on 25 April, 2 months after the official closing of the station, and 21 September, 1 month before opening in temperatures as low as –69°C (–92°F).

Communications increased at South Pole Station with the addition of 24-hour Iridium satellite telephones and improved voice-over-IP hardware. The addition of the 9-m Maritime Communications Satellite (Marisat)/Geostationary Operational Environmental Satellite (GOES) receiver and a 3-m backup receiver increased the transmission rate to as much as 3000 Kbps. Satellite communications are now available for approximately 17 hours each day through the utilization of four satellites: Land Earth Station 9 (LES 9), Marisat 2, GOES 3, and Tracking and Delay Relay Satellite 1 (TDRS 1). Support for the aging LES 9 satellite, transmitting at 38 Kbps, will soon end decreasing the satellite window by 5 hours. Technical details are found at the RPSC Web site www.polar.org.

Outreach Activities

Tourists not supported by the USAP rarely remain on the station long enough to get a full tour of the facilities, but CMDL personnel are always willing to give a tour of ARO if requested. During the austral summer, many official USAP-supported visitors arrived at ARO. Media groups including *CNN*, *The New York Times*, *Nippon Hoso Kyokai*, and *The Antarctic Sun* interviewed CMDL staff. Tours and presentations were given to many distinguished visitors during the two austral summers, including congressional staff members, seven members of the House Committee on Science, senior United States military officers, National Science Board members, and New Zealand dignitaries who visited the CMDL facility. The frequency of information requests from schools and individuals has increased over the past few years and is probably due to the increased number of people with Internet access.

1.4.2. PROGRAMS

Table 1.4 summarizes the programs at SPO for November 2002 to November 2003. Operational highlights for the 2001, 2002, and 2003 seasons are given below. The operations mentioned below are for these seasons unless a specific date is given. For more specific details, refer to the monthly station reports or the written and electronic equipment logs available upon request.

Gases

Carbon cycle green house gases. In situ measurements for carbon dioxide continued with no significant problems. In February 2002 the valve box was upgraded to incorporate the use of three calibration standards instead of two, and the computer was upgraded with improved software. In November 2003 the zero gas supply ran out and a low concentration working gas was used until replacement tanks arrived in January 2004.

Weekly flask samples were taken using the Martin and Kitzis Sampler (MAKS). Throughout the 2002 and 2003 seasons simultaneous sample flasks were filled through the analyzer. The MAKS was traditionally carried approximately 100 m into CAS for sampling, but during winter 2003 some samples were also taken on the ARO roof. To maintain consistency, and to eliminate any question of contamination, it was decided to continue sampling from CAS.

Halocarbons and other trace species. The CATS gas chromatograph (GC) operated with few interruptions during the 2002 and 2003 seasons. Interruptions were usually due to the occasional failure of components and routine maintenance. The instrument was shut down for annual maintenance in January 2002 and January 2003.

Stainless steel flasks were filled twice monthly throughout both seasons. In February 2002 the sample dates were changed to the 8th and the 22nd to remove weighting in the monthly mean calculations. In addition, glass flasks were filled at various depths from sample lines in the firn adjacent to the ARO facility. All flasks were stored inside ARO until station opening and were flown out on commercial airfreight by the second week of November.

Ozone and water vapor. During the 2002 winter the Thermo Environmental Instruments (TEI) surface ozone analyzer developed hardware problems that required the instrument to be shut down. The Dasibi, which had been kept online for a period of intercomparison, continued to run with no significant problems. A replacement TEI was installed shortly after station opening in November 2002. This instrument ran continuously throughout the 2003 season. The Dasibi will remain online as long as it is feasible to continue operations.

Routine measurements of total column ozone were taken three times daily during the austral summer months with the Dobson spectrophotometer. During the austral winter, measurements were taken May through August using the full moon as a light source.

The balloonborne stratospheric ozonesonde program continued with few problems. A second ground station was installed at ARO with an omni-directional antenna. Using remote control software, the data acquisition is now started at ARO from BIF, allowing personnel to monitor the flights while working on other projects at the laboratory. In addition to the normal ozonesonde schedule, there were 15 flights supporting the Quantitative Understanding of Ozone Losses by Bipolar Investigations (QUOBI) Match campaign.

Aerosols

Numerous electronic and mechanical problems plagued Meteorology Research Inc.'s (MRI) four-wavelength nephelometer during 2001 and 2002. The instrument was finally shut down for good in October 2002. A new Thermo Systems Incorporated (TSI) model 3563 three-wavelength nephelometer

Table 1.4. Summary of Measurement Programs at SPO in 2002 and 2003

Program/Measurement	Instrument	Sampling Frequency
Gases		
CO_2	LI-COR 6252	Continuous
CO_2, CH_4, CO, H_2, N_2O, SF_6, $^{13}C/^{12}C$ of CH_4, and $^{13}C/^{12}C$ and $^{18}O/^{16}O$ of CO_2	2.5-L glass flasks, through analyzer 2.5-L glass flasks, MAKS pump unit	1 pair wk^{-1} 1 pair wk^{-1}
Surface O_3	Dasibi and TEI surface ozone analyzers	Continuous
Total column O_3	Dobson spectrophotometer no. 82	3 sets day^{-1}
Ozone vertical profiles	Balloon borne ECC sonde	~3 wk^{-1}, spring/early summer, ~1 wk^{-1}, remainder of year
CFC-11, CFC-12, CFC-113, CFC-114/CFC-114a, HCFC-21, HCFC-22, HCFC-124, HCFC-141b, HCFC-142b, HFC-134a, HFC-152a, H-1211, H-1301, CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4, CH_3CCl_3, C_2Cl_4, CH_3Br, CH_2Br_2, $CHBr_3$, CH_3I, N_2O, SF_6, COS, C_6H_6	0.85-L, 2.5-L, or 3.0-L stainless steel flasks 2.5-L glass flasks, pump unit	2 pair mo^{-1} (~8th and 24th) 1 pair mo^{-1} (~8th)
CFC-11, CFC-12, CFC-113, HCFC-22, HCFC-142b, H-1211, H-1301, CH_3Cl, $CHCl_3$, CCl_4, CH_3CCl_3, CH_3Br, N_2O, SF_6, COS	Automated CATS GC	1 sample h^{-1}
Aerosols		
Condensation nuclei	Pollak CNC	1 set day^{-1}
	TSI CNC	Continuous
Optical properties	Four-wavelength nephelometer (removed 12/02)	Continuous
	TSI 3-wavelength nephelometer (installed 12/02)	Continuous
Solar Radiation		
Global (total) irradiance	Eppley pyranometer with Q filter	Continuous, summer
	Eppley pyranometer with RG8 filter	Continuous, summer
Direct irradiance	Eppley pyrheliometer with Q and RG8 filters (tracking NIP)	Continuous, summer
	Eppley pyrheliometer with Q, OG1, RG2, and RG8 filters (manual filter-wheel NIP)	~3 sets day^{-1}, summer
Diffuse irradiance	Eppley pyranometer with shading disk and Q filter	Continuous, summer
	Eppley pyranometer, black and white 8-48	Continuous, summer
Albedo	Eppley pyranometer with Q filter (downward facing)	Continuous, summer
	Eppley pyranometer with RG8 filter (downward facing)	Continuous, summer
	Eppley pyranometer with Q filter (on tower/down facing)	Continuous, summer
Optical Depth	SPO1-A multi-wavelength aureole sunphotometer	Continuous, summer
Terrestrial (IR) Radiation		
Upwelling and downwelling	Eppley pyrgeometers (2)	Continuous
Meteorology		
Air temperature (2 and 20-m heights)	Logan platinum resistance probe	Continuous
Pressure	Setra Capacitive pressure transducer	Continuous
	Mercurial barometer	2 wk^{-1}
Wind (speed and direction at 10-m height)	R.M. Young wind monitor	Continuous
Dew point temperature	TSL dew-point hygrothermometer	Continuous
Cooperative Programs		
CO_2, ^{13}C, N_2O (SIO)	5-L evacuated glass flasks	2 trios mo^{-1} (~1st and 15th)
O_2/N_2, CO_2 (SIO)	Pump unit, 5-L glass flasks	2 trios mo^{-1} (~1st and 15th)
Surface Air Sampling Program (DOE/EML) (natural and anthropogenic radionuclides)	High-volume pump and filters	Continuous (4 filters mo^{-1})
Interhemispheric $^{13}C/^{12}C$ (CSIRO) (CO_2, CH_4, CO, H_2, N_2O, and $^{13}C/^{12}C$ and $^{18}O/^{16}O$ of CO_2)	Pump unit, 0.5-L and 5-L flasks	2 pairs mo^{-1} (~1st and 15th)
H_2O_2 (Univ. of Arizona/DRI)	Surface snow sample collection	2 wk^{-1}
TFA (Univ. of Arizona/DRI)	Surface snow sample collection	1 mo^{-1}
Oxygen Isotopes (UCSD)	High-volume pump and filters	Continuous (1 wk^{-1})
Cloud profiling (NASA GSFC)	Micropulse lidar	Continuous

was installed in December 2002. This installation included the addition of a new computer and data acquisition system. The TSI condensation nuclei (CN) counter was connected to the upgraded system. The new aerosol system ran without significant problems until the laptop hard drive crashed in September 2003. Also in September 2003, the zero valve failed catastrophically. Both repairs were completed shortly after station opening in late October. The TSI CN counter ran with no significant problems. During the installation of the new aerosol system, the waveform on the CN counter was found to be irregular. The waveform was corrected in late December 2002 by aligning the optics.

Solar and Terrestrial Radiation

The solar instrumentation ran with no significant problems throughout both seasons. After sunset in March, most instruments are taken offline and brought inside for the winter months. The terrestrial radiation and longwave downwelling instruments are left operational year-round. At sunrise all the instruments are brought online, but the extreme cold at that time can put considerable strain on the trackers and fans. In February 2002 a switch was installed on the multiplexer whereby the offline instrument channels are not scanned.

The SP01 sunphotometer was replaced by the SP02 sunphotometer in November 2001. The SP02 sunphotometer was subsequently replaced by another SP02 sunphotometer in January 2003. The albedo rack was hand-excavated in November 2002 and the original post was reset in ice because the bottom of the post was buried in 3-m (10-ft) of snow after 6 years of accumulation. Several instruments were replaced in November 2002 as part of the routine calibration schedule. A second diffuse pyranometer was added to the roof in January 2003. In addition to the automated instrumentation, manual filter-wheel NIP measurements were recorded when the sun was not obscured by clouds.

Meteorology

The meteorology instrumentation operated with an increasing frequency of downtime in 2001 and in early 2002. Electrical noise on the data cables was thought to be the source of the problem that resulted in periods of no data. Software changes were made during the 2002 winter season to reset the data acquisition system when the system was down. Daily weather observations were recorded, and special observations were made when conditions changed significantly. Instrument calibrations and height adjustments were made during the austral summer seasons. The electrical service to the meteorological tower was raised in October 2002 to keep the cables and outlets from being buried in the snow.

Cooperative Programs

Scripps Institution of Oceanography (SIO). Sample flasks were filled twice monthly for later analysis at SIO.

U.S. Department of Energy Environmental Measurements Laboratory (DOE/EML). The Surface Air Sampling Program (SASP) pump ran continuously with no problems. Sample filters were changed every 8 days, and a sample blank was collected monthly. Samples are sent back to DOE/EML after station opening.

Commonwealth Scientific and Industrial Research Organization (CSIRO). Sample flasks were filled twice monthly for later analysis by CSIRO.

Desert Research Institute (DRI). Snow samples were collected twice weekly using a new surface scraping method. Samples are shipped frozen to DRI for chemical deposition analysis. Samples were also collected monthly for trifluoroacetate analysis.

University of California, San Diego (UCSD). Weekly rooftop filter samples were collected along with deposited snow. Frozen samples were shipped to UCSD for analysis.

NASA Goddard Space Flight Center. The cloud profiling micropulse lidar was maintained by CMDL staff for the 2002-2003 seasons.

1.5. TRINIDAD HEAD STATION

J.H. BUTLER AND M. IVES[1]

1.5.1. OPERATIONS

Trinidad Head is located along the rugged northern coast of California (41.054°N, 124.151°W, elevation 32.6 m (107 ft)), approximately 40 km (25 miles) north of Eureka, California, the main regional population center. The coastal climate is dominated by maritime influences, with moderate year-round temperatures and moderate-to-high humidity. To the immediate west of Trinidad Head is the unobstructed Pacific Ocean and to the east are redwood-dominated forest lands. The town of Trinidad represents the primary community in the immediate vicinity and supports approximately 400 year-round residents. The Telonicher Marine Laboratory (TML), a satellite facility of Humboldt State University (HSU), is also located in Trinidad.

Because of the characteristics of a relatively remote coastal location (insignificant anthropogenic influences and prevailing maritime airflow) the Trinidad Head site is an important, new addition to the CMDL Baseline Monitoring Network, providing an opportunity to observe and monitor both regional and global influences (Figure 1.5). Trinidad Head historically has been the site for both NOAA and Scripps Institution of Oceanography (SIO) supported trace gas monitoring networks and other regional scale air quality studies. The SIO Advanced Global Atmospheric Gases Experiment (AGAGE) group incorporated Trinidad Head into their network during 1995. The SIO group also supports instrumentation for in situ high-resolution measurements of atmospheric carbon dioxide and molecular oxygen. CMDL has launched balloonborne ozonesondes at Trinidad since 1997, and flask sampling for the CMDL Halocarbon and other Atmospheric Trace Species (HATS) program started in 2002.

The CMDL Trinidad Head Observatory (THD) was officially initiated during March of 2002 to coincide with the 2002 Intercontinental Transport and Chemical Transformation (ITCT) campaign, a major research project of the International Global Atmospheric Chemistry (IGAC) program. Instruments are currently housed within a 2.43-m (8 ft.) × 4.57-m (24 ft.) climate-controlled trailer. In addition to the aerosol and surface ozone instrumentation, the site also supports solar radiation and trace gas instrumentation. The station and location are shown in Figure 1.6.

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[1]Humboldt State University, California

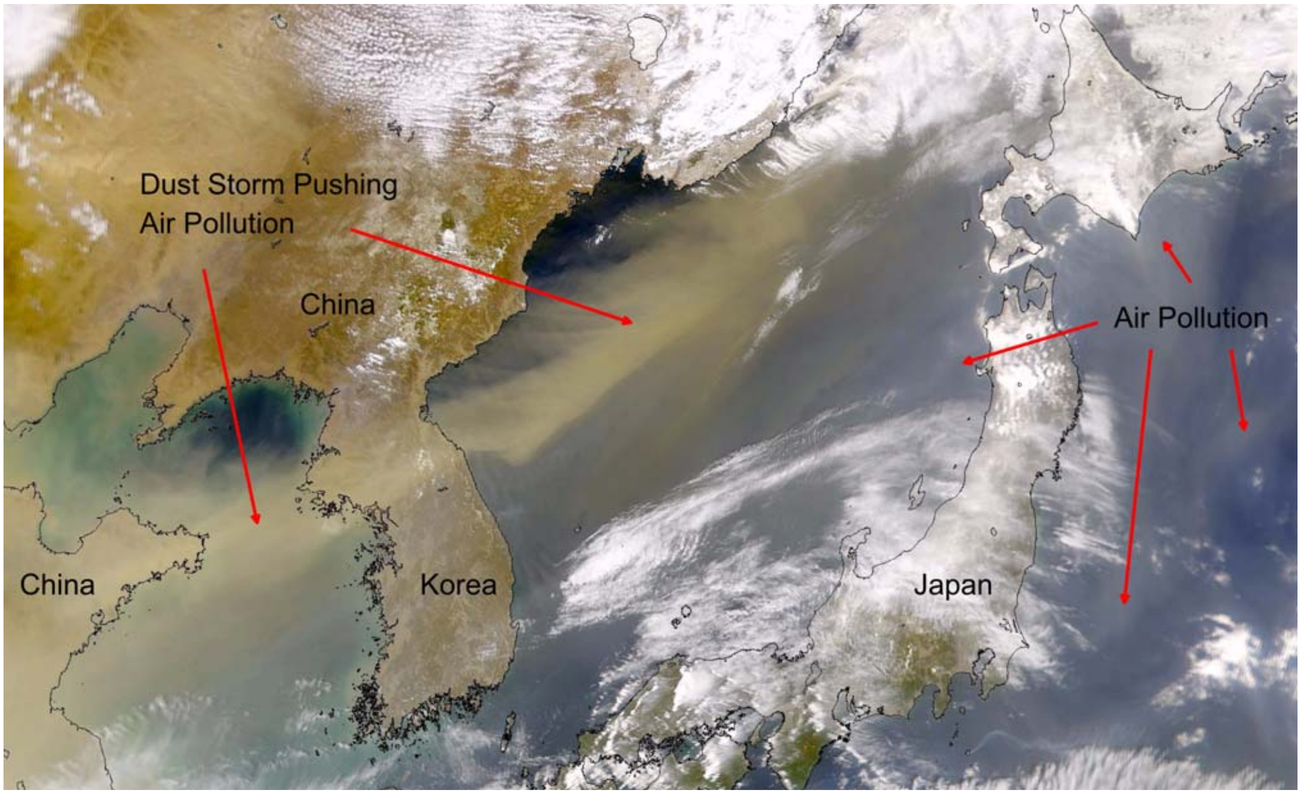


Figure 1.5. Windstorms in China and Mongolia move east across the Asian continent stirring up dust. As they move into the heavily populated regions of eastern China, the storms entrain air pollution from the urban areas and push the "soup" into the Pacific Ocean. Many of these events reach the United States within 5-7 days where the pollution and dust may be visible from California to the Rocky Mountains. THD was constructed to monitor these and similar events. The April 2001 storm crossed the entire United States (GSFC SeaWiFS image).

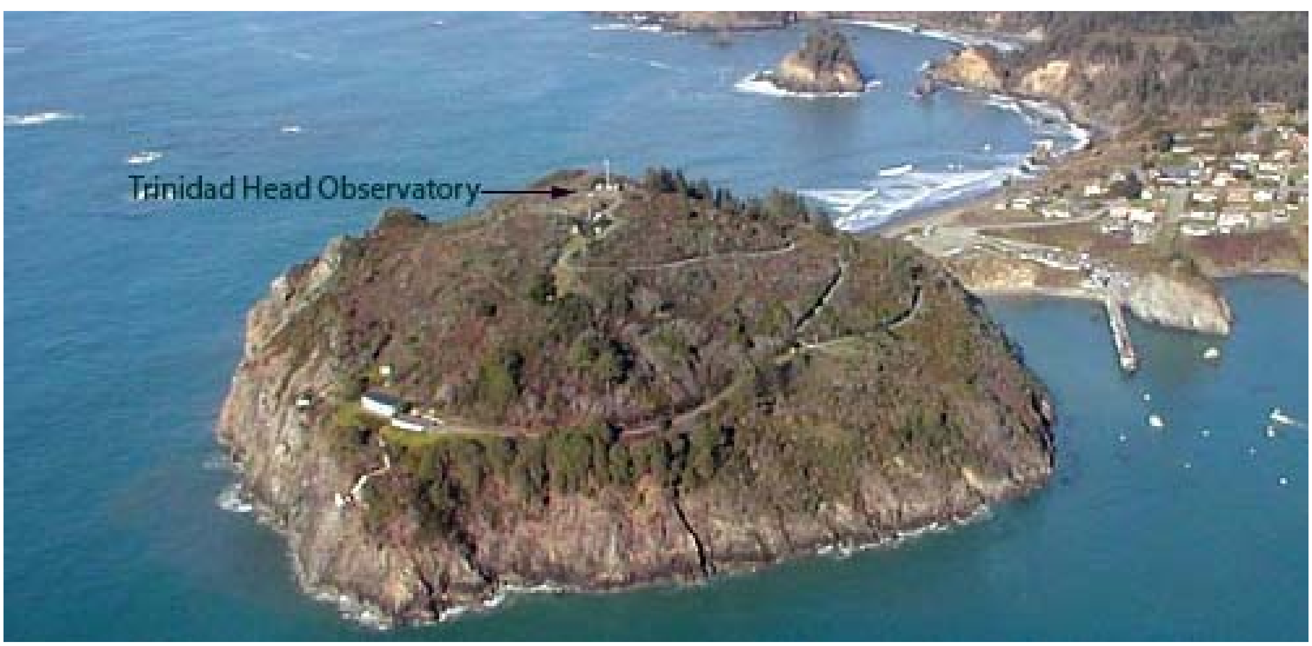


Figure 1.6. Trinidad Head Atmospheric Observatory: Latitude 40.8°N; Longitude 124.16°W; elevation 107 m. Instrumentation is mounted in a 7-m long modular unit and a 10-m tower located on the top of a hill at the end of a spit in Humboldt County northwest of Eureka, California.

Through a cooperative arrangement with Humboldt State University, the THD station is staffed daily by HSU personnel. Basic station maintenance includes equipment and instrument repair and replacement. Daily tasks include filter changes, instrumentation support, and manual data logging. Weekly tasks include instrument calibrations, filter/impactor changes, and shipment of filters to both PMEL and CMDL. The HSU staff also support special campaigns such as the 2002 ITCT.

The THD station includes a 12.2-m (40 ft.) aerial intake stack initially supported by scaffolding. However, during December 2003 the scaffolding was removed and replaced with a permanent tower. Future tasks include the shortening of the intake stack to more closely match the height of the installed tower.

The station's computer network system was revised in October 2003. Tasks included the configuring of the cable modem to support two static IP addresses, the installation of a wireless router/firewall, initiation of two-way networking for CMDL's Aerosol and Radiation (AERA) group and Ozone and Water Vapor (OZWV) group, and conversion of the aerosol instrumentation operating system from OS2 to Linux. The network is problem free and operates well since the modifications.

In addition to the THD station, TML supports the weekly launching of balloonborne ozone measuring ECC sondes. Since the initiation of the ozonesonde program in August 1997, over 340 ozonesonde launches have taken place. During the current reporting period, 118 ozonesondes were flown.

THD played host to the very successful 2002 ITCT campaign conducted during April and May 2002. The ITCT study involved a consortium of over 150 investigators from 33 government, university, and industry laboratories, notably the University of California at Berkeley, the University of California at Davis, the Georgia Institute of Technology, the University of Manchester Institute of Science and Technology, and Aerodyne Research, Inc. Three NOAA research laboratories were major participants and organizers, including CMDL, the Aeronomy Laboratory (AL), Boulder, Colorado, and the Pacific Marine Environmental Laboratory (PMEL), Seattle, Washington. The primary goal of the 2002 ITCT study focused on the chemical processing and removal dynamics of anthropogenic compounds originating from the eastern Asian continent and inflowing to the west coast region of North America with special emphasis on the Asian brown cloud.

THD is gearing up for the scheduled Cloud Indirect Effects Experiments (CIFEX) to be conducted at Trinidad Head during April 2004. The SIO-sponsored CIFEX campaign will focus on the Asian brown cloud and the relationship between aerosol microphysics and cloud microphysics and will investigate the impact of particles on cloud properties and precipitation efficiency. The CIFEX investigation will leverage and complement the results of the 2002 ITCT study.

The U.S. Climate Reference Network (CRN) is a network of climate stations under development as part of a NOAA-wide initiative. The primary goal of its implementation is to provide future long-term, high-resolution, homogeneous observations of temperature and precipitation that can be coupled to past long-term observations for the detection and attribution of present and future climate change. THD was visited during August 2003 by the CRN site selection committee inspector and assessed for site characteristics and site suitability before being selected tentatively for future CRN deployment.

1.5.2. Programs

Table 1.5 summarizes the programs at THD for 2002-2003. Operational highlights follow:

Gases

Carbon dioxide. Weekly AIRKIT sampling from 19 April 2002 through 18 October 2002. Weekly paired sampling using two AIRKITs resumed 8 September 2003 and continued through the reporting period. Comparisons between aluminum and gold plated aluminum condensers began 8 September 2003.

During September 2003 Atmospheric Observing Systems, Inc. deployed a high-resolution in situ continuous CO_2 monitoring system at THD. The system is expected to be operational in early 2004.

Surface ozone. In situ surface ozone monitoring by the Thermo Environmental Instruments (TEI) ultraviolet (UV) photometric ozone analyzer continued uninterrupted throughout the reporting period. A site visit by CMDL personnel during February 2003 focused on installation of a calibration bypass valve and new intake tubing for the TEI surface ozone analyzer. Currently, the TEI is operating well.

Ozonesonde balloons. Weekly ozonesonde flights continued throughout the reporting period with launches initiated from the TML launch site. In addition to the weekly flights, intensive daily flights were launched during the 2002 ITCT campaign. The construction of a balloon launching facility at TML greatly improved the launching success.

Halocarbons and other atmospheric trace species. Weekly flask sample pairs for the HATS group have been filled since February 2002 at the SIO AGAGE site. Flasks are returned to CMDL at Boulder for analysis. A future task will be moving the HATS flask sampling system to the THD station trailer and tower.

Aerosols

Aerosol measurements continued uninterrupted throughout the reporting period with minimal downtime. Because of the typically moist and corrosive environment, certain equipment (such as blowers) required frequent replacement. Planned modifications to the system design should alleviate some of the equipment failures. Frequent humidograph pump failure was found to be due to insufficient supply pressure. Elevation of the water reservoir has eliminated the pump and humidograph failures.

CMDL staff visited the station during December 2003. Tasks included the reattachment of the existing intake stack from the scaffolding to the permanent tower, repositioning of the anemometer and humidograph, CN counter replacement, and instrumentation calibration.

Solar Radiation and Meteorology

The solar radiation and meteorological instruments continued to operate throughout the reporting period. On 20 May 2003 CMDL staff replaced the precision spectral pyranometers (PSPs) and NIPs, added a pyrgeometer, and added Kipp & Zonen ventilators.

Table 1.5. Summary of Measurement Programs at THD in 2002 and 2003

Program/Measurement	Instrument	Sampling Frequency
Gases		
CO_2, CH_4, CO, H_2, N_2O, SF_6, and $^{13}C/^{12}C$ and $^{18}O/^{16}O$ of CO_2	2.5-L AIRKIT	1 pair wk^{-1}
Surface O_3	TEI Model 49C surface ozone analyzer	Continuous
Ozone vertical profiles	Balloonborne ECC sonde	1 wk^{-1}
CFC-11, CFC-12, CFC-113, CFC-114/CFC-114a, HCFC-21, HCFC-22, HCFC-124, HCFC-141b, HCFC-142b, HFC-134a, HFC-152a, H-1211, H-1301, CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4, CH_3CCl_3, C_2Cl_4, CH_3Br, CH_2Br_2, $CHBr_3$, CH_3I, N_2O, SF_6, COS, C_6H_6	0.85-L, 2.5-L, or 3.0-L stainless steel flasks 2.5-L glass flasks, pump unit	2 pair mo^{-1} (~1st and 15th) 1 pair mo^{-1} (~15th)
Aerosols		
Condensation nuclei	TSI CNC	Continuous
Optical properties	3-wavelength nephelometer (dry and humidified)	Continuous
Aerosol light absorption	Radiance Research PSAP	Continuous
Aerosol chemistry	Major ions, mass	1 day^{-1}
Solar Radiation		
Global (total) irradiance	Eppley pyranometer with Q filter	Continuous
Direct irradiance	2-Eppley pyrheliometer with Q and RG8 filters (tracking NIP)	Continuous
Diffuse irradiance	Eppley pyranometer with shading disk and Q filter Eppley pyranometer, black and white 8-48	Continuous
Optical Depth	SP02-A multi-wavelength sunphotometer	Continuous
Terrestrial (IR) Radiation		
Downwelling	Eppley pyrgeometer	Continuous
Meteorology		
Air temperature (2-m)	Vaisala platinum resistance probe	Continuous
Pressure (2-m)	Setra capacitive pressure transducer	Continuous
Wind (speed and direction)(2-m)	R.M. Young wind monitor	Continuous
Relative humidity (2-m)	Vaisala meter	Continuous
*ITCT/IGAC**		
VOCs (Univ. California, Berkeley)	TEI 48C NDIR nondispersive infrared absorption	Continuous
CO_2 (Univ. California, Berkeley)	Li-Cor LI-6262 infrared absorption	Continuous
O_3 (Univ. California, Berkeley)	Dasibi 1008-RS UV photometric analyzer	Continuous
NO, NO_y (NOAA AL)	Chemiluminesence custom-built instrument	Continuous
PAR (Univ. California, Berkeley)	Li-Cor LI 190SZ quantum sensor	Continuous
Wind speed (Univ. California, Berkeley)	R.M. Young propeller wind monitor	Continuous
Air temperature (Univ. California, Berkeley)	Campbell Scientific HMP45C temperature and RH probe	Continuous
Size-resolved aerosol chemistry, and total mass (NOAA PMEL)	Dionex ion chromatograph	1 day^{-1}
RN-222 (NOAA PMEL)	Filter sampler	Continuous
Aerosol chemical composition (UMIST)	Mass spectrometers	Continuous
Aerosol chemical composition (Georgia Tech.)	Particle into-liquid sampler	Continuous
Aerosol chemical composition (Univ. California, Davis)	Davis rotating-drum unit	Continuous

*Measurements were made for the Intercontinental Transport and Chemical Transformation (ITCT) research project of the International Global Atmospheric Chemistry (IGAC) program in March 2003 in addition to on-going CMDL measurements.

PMEL, Pacific Marine Environmental Laboratory, Seattle, Washington

UMIST, University of Manchester Institute of Science and Technology (UK)

On-site staff replaced the NIP detectors on 28 October 2003 and the SPO2 sunphotometer on 17 November 2003. Recently the THD station trailer was fitted with a skylight port in anticipation of the installation of a lidar system. The lidar installation is expected to be complete prior to the initiation of the CIFEX campaign.

1.6. Meteorological Measurements

T. Mefford

1.6.1. Meteorology Operations

Introduction

The climatology of surface meteorological observations at four of the five CMDL established observatories is based on hourly average measurements of the prevailing wind direction and wind-speed (WS), barometric pressure, ambient and dewpoint temperatures, and precipitation amounts. The meteorological sensors in use were selected for their high accuracy as well as their ability to withstand the extreme conditions of the polar regions. Data is recorded as 1-minute averages so that the variability within the hourly averages can be determined. To the extent that is possible, World Meteorological Organization (WMO) siting standards [*WMO*, 1969] are followed. In addition, a thermometer is positioned at the top of the sampling tower at BRW, MLO, and SPO, while MLO and SPO also have thermometers at the middle of the sampling towers. These additional thermometers are used to measure the temperature gradient and to determine the stability of the surface boundary layer.

Peterson and Rosson [1994] give a detailed description of the PC-based data acquisition system. Table 1.6 describes the instrument deployment as of 31 December 2003.

Data Management

The meteorological data acquisition system gathers data from sensors that operate continuously at BRW, MLO, SMO, and SPO. Data are transferred to Boulder on a daily basis via the Internet. Preliminary analyses of prevailing wind direction and wind-speed, barometric pressure, ambient and dew point temperatures, and precipitation amounts are performed in Boulder and a report is sent to each of the observatories on a daily basis.

A comparison of the number of data points recorded against that expected for the year was used to monitor the system's performance. Table 1.7 shows the performance of each system in 2002 and 2003. On average, the meteorological data acquisition system for the four observatories operated 91.31% and 97.16% of the time for 2002 and 2003, respectively. Because of the remoteness of the observatories, power outages are common and are the main reason for data loss. Hardware failure, system restarts, and system maintenance are the other reasons. At BRW and SPO rime, snow, and ice occasionally build up on the sensors and have to be removed manually during the winter.

1.6.2. Station Climatologies

The 27-year station climatologies are an important record for the interpretation of measured values of aerosols, trace gases, atmospheric turbidity, solar radiation, and for analyses of long-term changes in the records themselves. The records also serve to outline periods of local contamination.

Barrow

In Figure 1.7, wind roses of hourly average prevailing wind direction and wind-speed at BRW are presented in 16 direction classes and 3 speed classes. Winds from the "clean air" sector, north-northeast to southeast occurred 55.1% of the time in 2002 and 53.4% in 2003 compared to 61.7% for the 25-year period from 1977 through 2001 (Figure 1.8). Wind speeds in excess of 10 m s^{-1} in 2002 (11.8%) were more frequent than the 25-year climatology (10.7%), whereas in 2003 (9.5%) they were less frequent than the 25-year climatology. The average wind speeds of 5.8 m s^{-1} in 2002 and 5.7 m s^{-1} in 2003 were slightly below the long-term average (6.0 ms^{-1}). April 2002 set a maximum wind-speed record of 20.5 m s^{-1}.

The average air temperatures of –9.7°C in 2002 and –10.6°C in 2003 (Table 1.8) were both warmer than the 25-year average of –12.2°C. The barometric pressure in 2002 (1013.4 hPa) and 2003 (1013.3 hPa) were both below the 25-year average of 1014.1 hPa. July 2002 recorded a new record high barometric pressure reading and April 2002 set a new record low barometric pressure reading. The summertime precipitation amounts for 2002 (71 mm) and 2003 (54 mm) were above the long-term average of 39 mm.

A preliminary analysis of the temperature data from BRW suggests that the Technical Services Laboratory (TSL) hygrothermometer reads systematically warmer than the Logan Enterprises (4150) platinum resistance probe (RTD) in winter. These probes have been operating at the same height above ground (2 m), side-by-side, since 15 April 1994. The reason for this appears to be that snow, rime, and/or frost tend to block the flow of air into the TSL. Without adequate aspiration, the probe gives an elevated reading. Table 1.8 shows the temperature data from the RTD (now the official BRW temperature) with the suspect TSL data in italic. Both sets of data are available for download at ftp://ftp.cmdl.noaa.gov/met/hourlymet/brw/. Note: Both data sets for BRW include the dew point temperature from the TSL instrument; thus caution must be used if deriving relative humidity from these data.

Another result of the analysis is that calibration errors were identified in the BRW temperature data from 1 March 1983 to 10 August 1984. Therefore, these data are flagged as missing or in error until corrections can be made in the archived files.

Mauna Loa

The climatology of MLO is best understood when it is considered in two distinctive wind regimes, the night (downslope) period (1800-0559) Hawaiian Standard Time (HST) and the day (upslope) period (0600-1759 HST). The 25-year (1977-2001) night and day wind chart illustrate the two distinct wind regimes (Figure 1.9).

For the night regime, the 25-year wind rose (Figure 1.9) shows that 89.8% of all winds observed had a southerly component. The percentage of occurrence of southerly winds in 2002 was 90.1% (Figure 1.10) and 89.4% in 2003 (Figure 1.11). Pressure gradient controlled winds (WS ≥ 10 m s^{-1}) from predominately westerly

Table 1.6. CMDL Meteorological Sensor Deployment 31 December 2003

	BRW		MLO		SMO		SPO	
Sensor	Serial No.	Elevation* (m)	Serial No.	Elevation* (m)	Serial No.	Elevation* (m)	Serial No.	Elevation* (m)
Primary anemometer†	14584	10.5	23186	10.2	15945	22.9	14583	10.3
Secondary anemometer†			15946	38.2				
Pressure transducer‡	374199	9.5	374198	3398.4	374200	78.5	358960	2841.0
Mercurial barometer	641	9.5			961	78.5	1215A	2841.0
Air temperature A§		2.4		2.0		18.9		2.1
Air temperature B§¶				9.0				13.0
Air temperature C§¶		15.7		37.4		18.9		21.9
Air temperature D**		2.9		2.0		18.9		1.8
Dewpoint temperature	G0001	2.9	G0004	2.0	G0008	18.9	G0007	1.8
Rain gauge		~4		0.8		~4		

*Heights are in meters above surface, except for the pressure transducer and mercurial barometer, which are with respect to mean sea level (MSL).
†Propeller anemometer, model no. 05103, R. M. Young Company, Traverse City, Michigan.
‡Pressure transducer, model no. 270, Setra Systems, Acton, Massachusetts.
§Platinum resistance probe, Logan 4150 Series, Logan Enterprises, Liberty, Ohio.
¶Thermometers, positioned at the middle and top of the local sampling tower to facilitate an estimation of boundary layer stability, except at SMO where the sensors are at the same height.
**Hygrothermometer, Technical Services Laboratory model no. 1088-400, Fort Walton Beach, Florida.

Table 1.7. CMDL Meteorological Operations Summary

Station	Expected Number of Data Points	Percent Data Capture	Number of Missing Data Points
		2002	
BRW	4,204,800	97.02%	125,227
MLO	6,225,120	88.07%	742,431
SMO	4,204,800	95.33%	196,366
SPO	4,204,800	84.82%	638,280
Average		91.31%	
		2003	
BRW	4,204,800	97.27%	114,780
MLO	5,781,600	96.70%	190,550
SMO	4,204,800	97.09%	122,529
SPO	4,204,800	97.58%	101,704
Average		97.16%	

and southeasterly directions, occurred 3.8% of the time in 2002 and 4.9% in 2003, both of which were below the 25-year average of 6.8%. The annual average wind speed for 2002 and 2003 (Tables 1.9 and 1.10) were both below the long-term average of 4.7 m s^{-1}). The upslope, or northerly component winds (north-northwest through east-northeast) that occurred 3.2% of the time in 2002 and 2.8% in 2003, are the result of the daytime upslope flow extending into the early evening hours.

For the day regime, the 2002 and 2003 wind roses (Figures 1.10 and 1.11) indicate that winds from the west-northwest through east-southeast occurred 73.3% of the time in 2002 and 70.4% of the time 2003, compared with 69.9% for the 25-year climatology (Figure 1.9). Pressure-gradient-controlled winds (WS ≥ 10 m s^{-1}) occurred 2.7% of the time in 2002 and 4.3% of the time in 2003, both of which were lower than the 25-year average of 5.7%. In 2002 and 2003, the pressure-gradient winds, which are usually associated with storms, followed the expected pattern of fewer occurrences during the day regime. The day wind chart is more uniformly distributed in the light-wind classes than the night wind chart. This is due to the occurrence of variable wind directions during the transition periods at dawn and dusk, most of which are included in this regime.

The average ambient temperature for 2002 (Table 1.9), combining both day and night regimes, was 6.5°C, which is lower than the long-term average of 7.1°C, while the 8.0°C in 2003 was above the long-term average. The average barometric pressure for both 2002 and 2003 (680.5 hPa) equaled the long-term average of 680.5. The total precipitation amount in 2002 (452 mm) was considerably higher than the long-term average of 343 mm, while 2003 (329 mm) was slightly below the long-term average.

Samoa

A comparison of SMO's 2002 and 2003 wind roses (Figure 1.12) to that of the 25-year period (Figure 1.13) shows a considerably higher percentage (75.6%) of "clean air" sector winds (north-northwest through southeast) in 2002 and 2003 (63.4%) than the long-term average of 59.6%. The occurrence of winds in the 10 m s^{-1} or greater class was 18.1% in 2002 and 2003, whereas the expected occurrence based on the 25-year average is 5.5%. The annual average wind speed for 2002 (6.6 m s^{-1}) and 2003 (6.5 m s^{-1}) (Table 1.11) were both above long-term-average of 5.1 m s^{-1}. June, July, and August 2002 set a new maximum speed record as did March, May, and November 2003.

The average ambient temperature for 2002 (27.0°C) equaled the 25-year average of 27.0°C and 2003 (26.8°C) was slightly cooler than the long-term average. The average barometric pressures for 2002 (1000.7 hPa) and 2003 (1000.5 hPa) were both lower than the 25-year average of 1000.9 hPa. A low pressure record was set in May 2002. The precipitation amounts in both 2002 (2485 mm) and 2002 (2234 mm) were higher than the climatological average of 1797 mm.

South Pole

The distribution of the surface wind direction in 2002 and 2003 (Figure 1.14) shows a percentage of "clean air" sector (grid north-northwest through east-southeast) winds of 92.6% in 2002 and

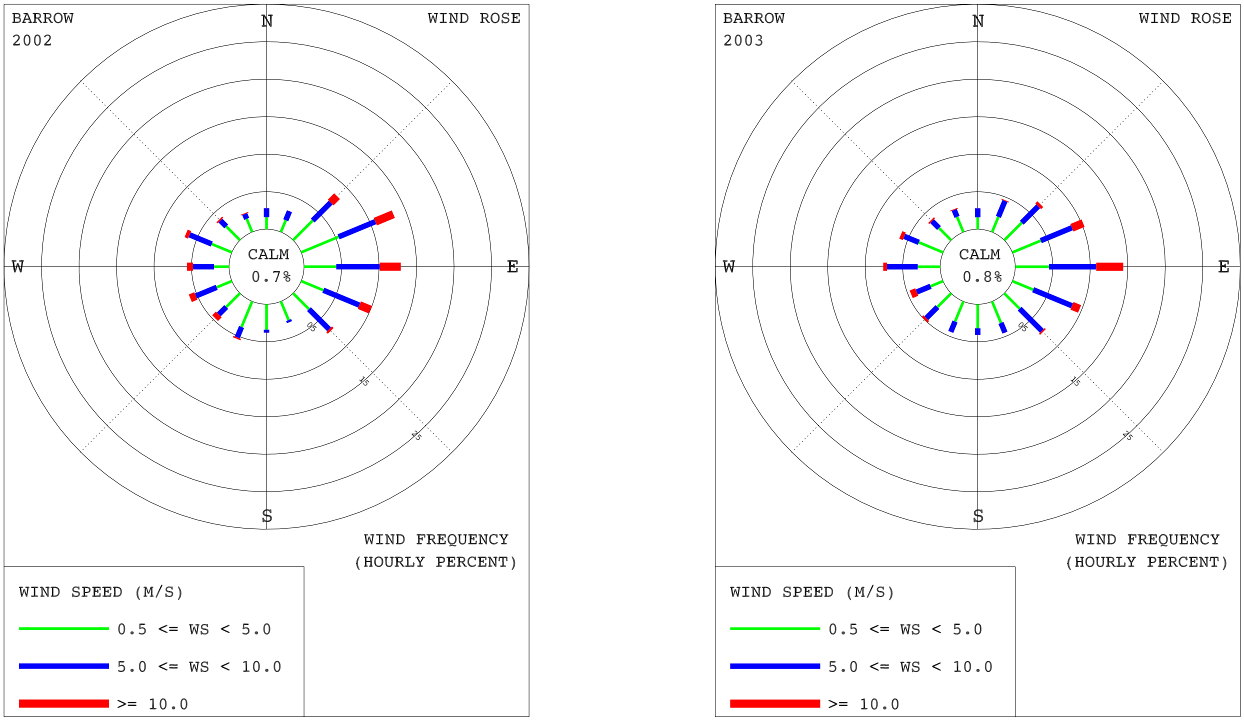


Figure 1.7. Wind roses of the surface winds at BRW for 2002 (left) and 2003 (right). The distributions of prevailing wind direction and speed are given in units of percent occurrence for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graphs.

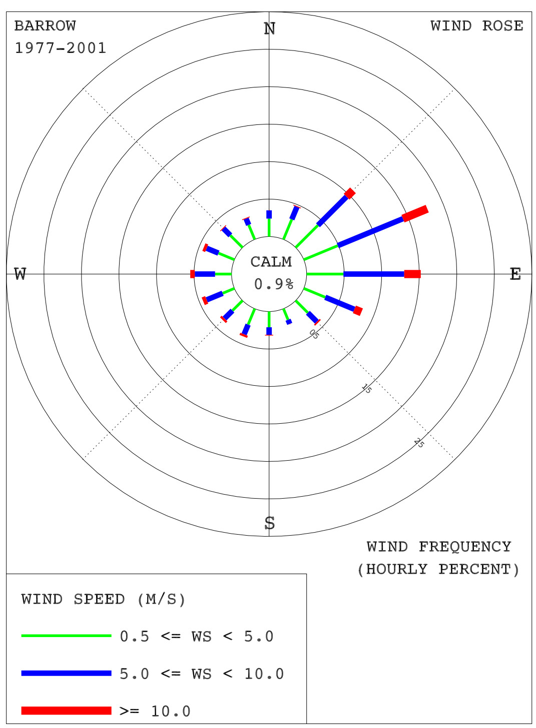


Figure 1.8. Wind rose of the surface winds at BRW for 1977-2001. The distributions of prevailing wind direction and speed are given in units of percent occurrence for the 25-year period for16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graph.

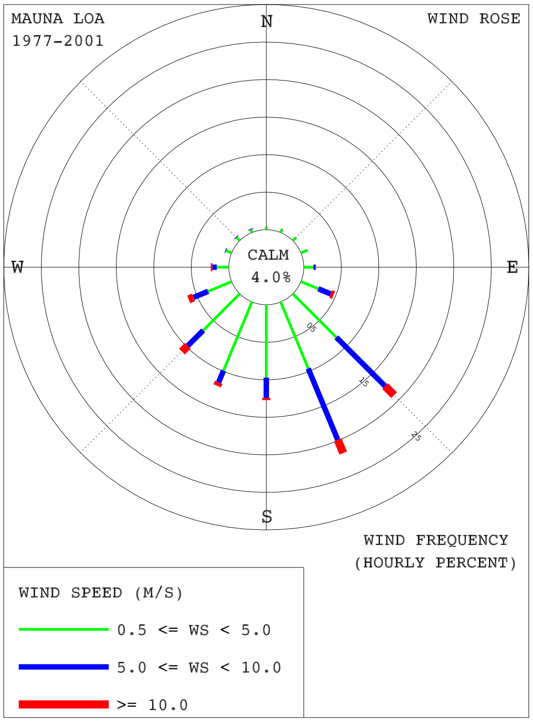
Table 1.8. BRW 2002 and 2003 Monthly Climate Summary

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
							2002						
Prevailing wind direction	ENE	E	E	W	ENE	E	ESE	WSW	SE	ESE	ENE	E	ENE
Average wind speed (m s^{-1})	4.2	5.4	4.7	5.9	6.4	5.2	5.3	5.1	5.2	7.0	7.5	6.6	5.8
Maximum wind speed* (m s^{-1})	13.9	17.3	15.6	20.5	15.8	13.3	12.1	18.2	12.7	16.2	17.9	16.0	20.5
Direction of max. wind* (deg.)	119	92	113	222	67	242	233	222	260	317	68	251	222
Average station pressure (hPa)	1011.7	1016.5	1029.2	1017.7	1018.4	1011.4	1012.0	1010.5	1005.4	1010.8	1011.6	1007.0	1013.4
Maximum pressure* (hPa)	1038.2	1030.3	1051.8	1042.6	1040.3	1024.4	1031.9	1031.9	1025.7	1031.4	1028.1	1029.3	1051.8
Minimum pressure* (hPa)	982.4	1000.3	1009.1	977.9	1004.0	992.0	995.5	998.6	988.4	984.5	989.8	990.6	977.9
Average air temperature (°C) †	-26.8	-27.3	-18.6	-16.3	-4.0	0.0	2.8	2.6	2.4	-4.2	-13.4	-18.3	-9.7
	-20.9	*-23.7*	*-18.2*	*-13.5*	*-4.1*	*0.0*	*2.8*	*2.6*	*2.3*	*-4.2*	*-13.4*	*-18.0*	*-7.3*
Maximum temperature* (°C) †	-5.9	-15.4	-3.3	1.7	6.5	6.9	17.6	15.4	11.6	2.5	-0.5	-7.0	17.6
	-6.0	*-15.3*	*-3.2*	*1.8*	*6.7*	*6.9*	*17.6*	*15.8*	*11.9*	*2.4*	*-0.7*	*-6.9*	*17.6*
Minimum temperature* (°C) †	-42.3	-37.5	-33.6	-31.9	-18.7	-7.9	-3.6	-2.2	-2.3	-22.2	-22.8	-30.9	-42.3
	-36.1	*-34.7*	*-33.3*	*-29.6*	*-18.6*	*-7.7*	*-3.7*	*-2.4*	*-2.4*	*-21.8*	*-22.7*	*-30.4*	*-36.1*
Average dewpoint temperature (°C)	-23.7	-26.8	-20.8	-15.7	-5.9	-1.5	1.0	1.3	1.0	-6.8	-15.7	-20.5	-9.4
Maximum dewpoint temperature (°C)	-7.2	-18.0	-4.7	-0.6	1.3	5.2	10.1	9.2	9.0	1.5	-1.0	-8.2	10.1
Minimum dewpoint temperature (°C)	-40.1	-38.4	-36.5	-32.5	-20.6	-9.1	-4.5	-3.1	-5.8	-24.4	-25.6	-33.4	-40.1
Precipitation (mm)	0	0	0	1	1	12	4	16	37	0	0	0	71
							2003						
Prevailing wind direction	E	ENE	NE	SE	E	ESE	W	E	W	NNE	S	E	E
Average wind speed (m s^{-1})	5.3	5.4	4.6	5.1	5.6	5.4	6.0	5.6	5.6	6.8	5.3	7.5	5.7
Maximum wind speed* (m s^{-1})	13.5	15.6	11.4	13.9	14.2	11.0	18.5	13.5	13.6	15.1	12.6	19.5	19.5
Direction of max. wind* (deg.)	98	100	332	116	237	101	261	78	252	62	116	106	106
Average station pressure (hPa)	1015.3	1023.2	1023.3	1015.8	1014.1	1014.2	1006.9	1011.1	1012.4	1011.1	1005.7	1007.4	1013.3
Maximum pressure* (hPa)	1036.4	1042.4	1046.2	1031.8	1036.3	1022.2	1017.6	1030.7	1034.3	1035.8	1032.8	1033.2	1046.2
Minimum pressure* (hPa)	985.5	1009.6	1006.9	994.4	998.0	1003.7	988.1	994.6	987.5	989.9	978.6	988.5	978.6
Average air temperature (°C) †	-23.4	-26.4	-23.5	-13.6	-5.3	0.3	4.1	1.9	-0.1	-3.9	-15.8	-21.7	-10.6
	-23.0	*-25.9*	*-21.6*	*-13.8*	*-5.3*	*0.3*	*4.1*	*1.9*	*0.0*	*-3.8*	*-15.6*	*-21.1*	*-10.0*
Maximum temperature* (°C) †	-11.0	-15.8	-7.7	-0.7	1.6	8.8	15.5	14.7	7.0	3.5	0.8	-5.8	15.5
	-10.9	*-15.6*	*-6.5*	*-0.2*	*1.7*	*8.8*	*15.9*	*14.9*	*7.0*	*3.5*	*1.1*	*-5.1*	*15.9*
Minimum temperature* (°C) †	-42.4	-34.9	-35.3	-29.1	-16.4	-3.8	-1.6	-2.1	-7.1	-17.1	-33.6	-34.2	-42.4
	-42.1	*-34.7*	*-30.7*	*-28.2*	*-16.4*	*-3.8*	*-1.5*	*-2.0*	*-4.5*	*-16.9*	*-33.2*	*-32.9*	*-42.1*
Average dewpoint temperature (°C)	-26.0	-29.1	-24.7	-18.0	-7.1	-1.2	2.1	0.3	-2.2	-5.7	-18.1	-24.1	-12.3
Maximum dewpoint temperature (°C)	-13.0	-17.8	-8.6	-1.9	-0.3	7.0	9.6	8.1	6.1	2.1	-0.6	-7.4	9.6
Minimum dewpoint temperature (°C)	-46.1	-38.7	-34.2	-31.7	-17.9	-4.7	-2.9	-4.8	-6.5	-19.1	-36.5	-37.7	-46.1
Precipitation (mm)	0	0	0	3	0	0	13	17	13	8	0	0	54

Instrument heights: wind, 10.5 m; pressure, 9.5 m (MSL); air temperature, 2.9 m; dewpoint temperature, 2.9 m. Wind and temperature instruments are on a tower 25-m northeast of the main building.

†Data in italic is from the TSL hygrothermometer and data in black is from the platinum resistance probe.

*Maximum and minimum values are hourly averages.



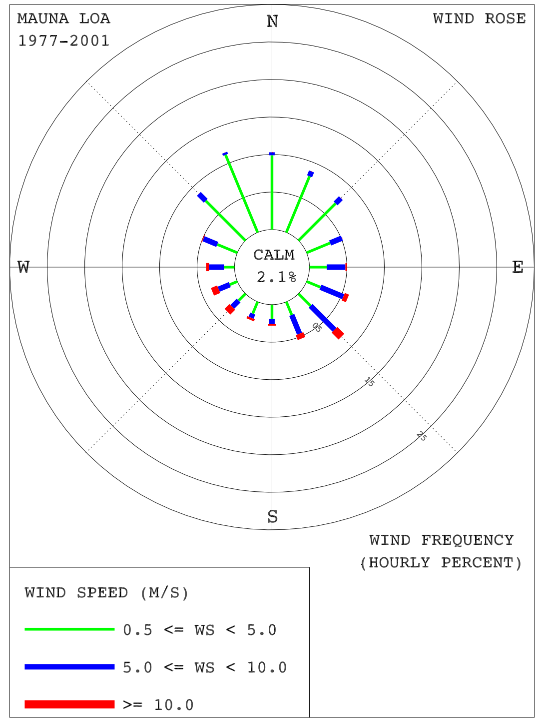
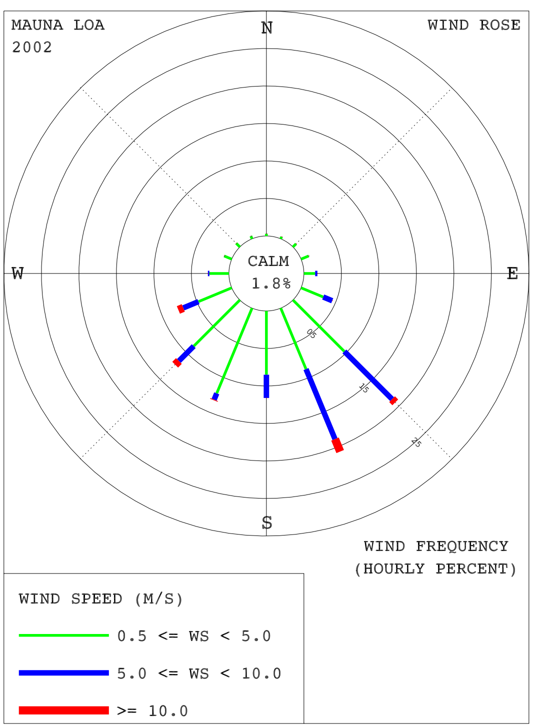


Figure 1.9. Wind roses of the surface winds at MLO for 1977-2001 night (left) and day (right). The distributions of prevailing wind direction and speed are given in units of percent occurrence for the 25-year period for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graph. The night wind rose is from data between 1800 and 0559 Hawaiian Standard Time (HST). The day wind rose is from data between 0600 and 1759 HST.



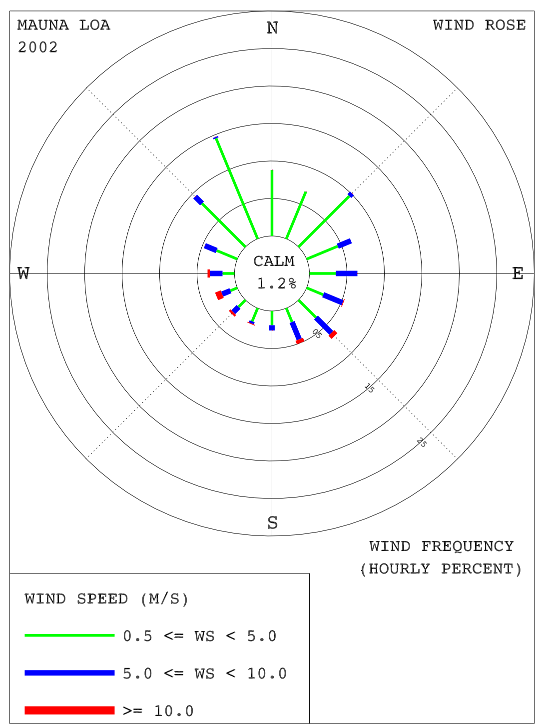


Figure 1.10. Wind roses of the surface winds at MLO for 2002 night (left) and day (right). The distributions of prevailing wind direction and speed are given in units of percent occurrence for the 25-year period for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graph. The night wind rose is from data between 1800 and 0559 Hawaiian Standard Time (HST). The day wind rose is from data between 0600 and 1759 HST.

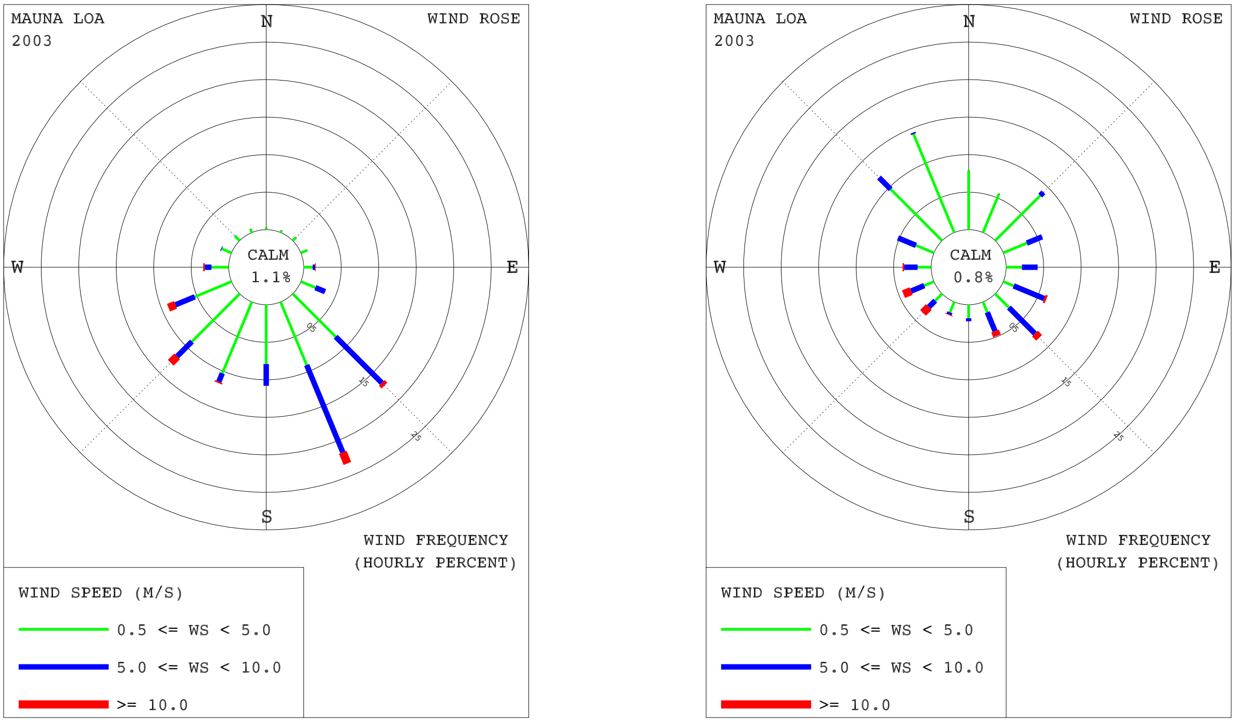


Figure 1.11. Wind roses of the surface winds at MLO for 2003 night (left) and day (right). The distributions of prevailing wind direction and speed are given in units of percent occurrence for the 25-year period for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graph. The night wind rose is from data between 1800 and 0559 Hawaiian Standard Time (HST). The day wind rose is from data between 0600 and 1759 HST.

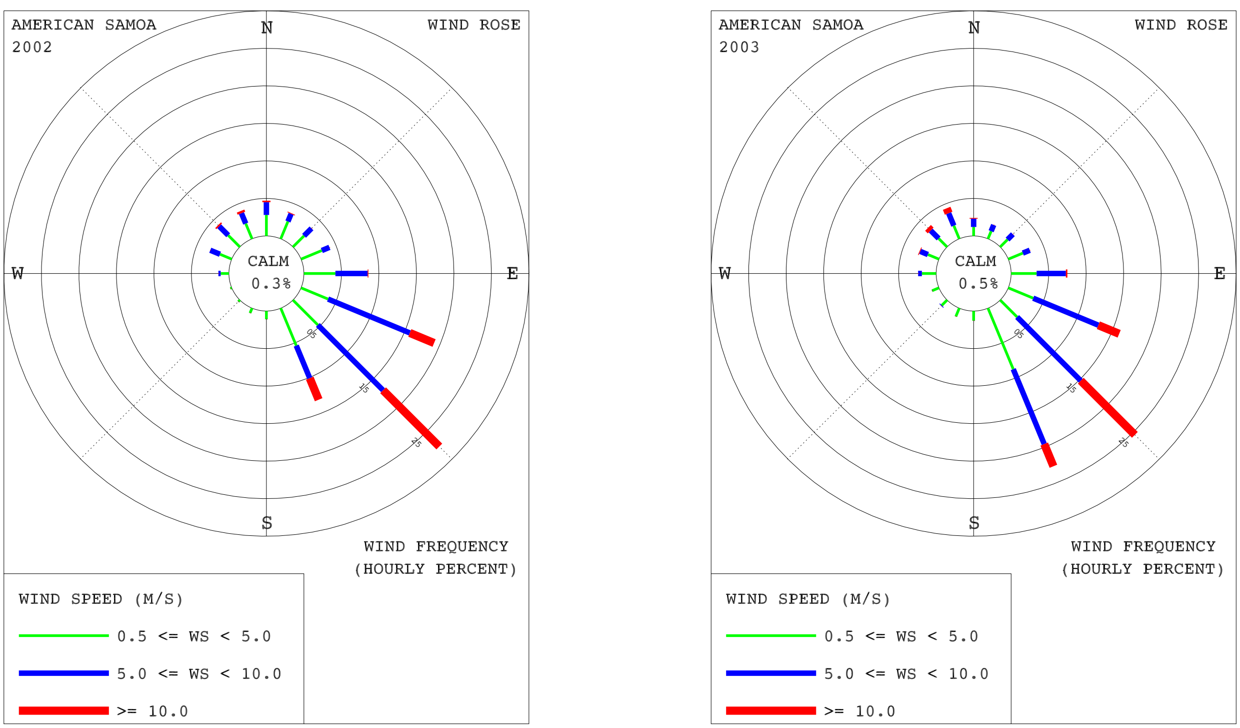


Figure 1.12. Wind roses of the surface winds at SMO for 2002 (left) and 2003 (right). The distributions of prevailing wind direction and speed are given in units of percent occurrence for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graphs.

Table 1.9. MLO 2002 Monthly Climate Summary

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
							Night						
Prevailing wind direction	SW	SE	SW	SW	SE	SSE	SE	SSE	SSW	SSE	SSE	SSE	SSE
Average wind speed (m s^{-1})	4.8	3.9	4.1	4.7	3.5	5.4	5.1	3.0	2.9	3.7	4.5	4.4	4.2
Maximum wind speed* (m s^{-1})	11.5	10.8	12.1	12.7	10.8	14.4	12.5	10.6	8.0	14.1	11.0	12.3	14.4
Direction of max. wind* (deg.)	226	251	224	231	239	154	163	166	159	156	158	160	154
Average station pressure (hPa)	679.3	679.3	679.2	679.7	680.7	681.0	681.7	681.4	680.6	680.2	681.0	681.2	680.5
Maximum pressure* (hPa)	683.2	683.3	682.8	684.3	683.1	684.8	683.7	683.8	683.8	684.0	684.5	684.6	684.8
Minimum pressure* (hPa)	675.2	675.8	676.0	676.5	676.7	678.1	679.1	678.8	677.5	677.4	677.4	678.4	675.2
Average air temperature (°C)	3.2	2.0	1.8	4.4	4..2	5.9	6.0	5.5	5.5	4.4	6.8	4.7	4.6
Maximum temperature* (°C)	9.6	7.7	7.3	9.6	10.7	11.6	11.2	11.2	12.4	9.0	11.4	11.6	12.4
Minimum temperature* (°C)	-2.9	-3.0	-2.2	1.0	0.7	1.1	1.6	1.7	0.9	-0.1	1.8	-0.3	-3.0
Average dewpoint temperature (°C)	-11.2	-14.7	-9.7	-10.7	-2.3	-13.6	-9.5	-6.7	-11.5	-13.1	-16.6	-19.9	-11.5
Maximum dewpoint temperature (°C)	4.2	2.0	5.2	6.0	7.2	5.0	6.4	6.8	6.4	5.6	1.6	2.4	7.2
Minimum dewpoint temperature (°C)	-33.4	-30.8	-28.0	-26.5	-15.5	-30.4	-26.8	-25.7	-30.5	-31.7	-30.1	-33.9	-33.9
Precipitation (mm)	53	0	1	13	34	0	1	2	4	1	0	1	110
							Day						
Prevailing wind direction	W	NW	NNW	NNW	NNW	SE	NE	NNW	NNW	NE	ENE	NNW	NNW
Average wind speed (m s^{-1})	4.4	3.4	4.1	4.9	3.2	4.4	4.2	2.8	2.7	3.4	3.6	3.4	3.7
Maximum wind speed* (m s^{-1})	9.9	8.6	14.5	13.7	12.3	14.8	11.4	9.0	7.4	10.8	11.3	12.3	14.8
Direction of max. wind* (deg.)	264	103	239	264	241	143	163	151	151	161	125	149	143
Average station pressure (hPa)	679.3	679.2	679.3	679.7	680.8	681.3	681.9	681.4	680.7	680.2	681.0	681.1	680.5
Maximum pressure* (hPa)	683.3	683.6	683.4	684.2	683.1	684.7	684.0	683.7	683.8	684.3	685.2	685.2	685.2
Minimum pressure* (hPa)	675.0	676.1	675.8	676.8	677.0	678.8	679.6	678.4	677.8	677.5	677.4	678.2	675.0
Average air temperature (°C)	6.1	5.1	5.5	8.5	7.4	10.5	10.2	9.0	9.4	8.2	11.1	8.9	8.4
Maximum temperature* (°C)	15.9	11.8	12.2	14.4	14.0	15.4	15.1	15.6	14.6	14.0	16.9	14.8	16.9
Minimum temperature* (°C)	-3.3	-2.9	-2.2	2.4	1.9	4.0	3.1	2.7	1.9	0.9	2.2	0.2	-3.3
Average dewpoint temperature (°C)	-8.3	-11.0	-4.4	-4.9	1.6	-6.7	-4.0	-1.6	-3.8	-6.8	-10.9	-13.7	-6.1
Maximum dewpoint temperature (°C)	6.0	5.9	5.3	7.7	7.3	6.8	8.4	7.8	8.6	7.6	6.2	7.0	8.6
Minimum dewpoint temperature (°C)	-32.2	-32.0	-29.6	-25.0	-15.3	-29.5	-25.5	-23.2	-31.7	-31.2	-27.1	-34.0	-34.0
Precipitation (mm)	51	19	0	27	134	0	32	45	21	13	0	0	342

Instrument heights: wind, 10.2 m; pressure, 3398.4 m (MSL); air temperature, 2.0 m; dewpoint temperature, 2.0 m. Wind and temperature instruments are on a tower 15 m southwest of the main building.

*Maximum and minimum values are hourly averages.

Table 1.10. MLO 2003 Monthly Climate Summary

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
							Night						
Prevailing wind direction	SW	SE	SSE	SSE	S	SE	SE	SSE	SSE	SSE	SSE	SSE	SSE
Average wind speed (m s^{-1})	6.1	4.8	4.6	2.9	3.4	4.0	4.3	4.0	3.5	4.9	6.3	5.7	4.5
Maximum wind speed* (m s^{-1})	13.6	13.5	11.7	10.0	13.4	10.5	11.1	10.4	12.2	13.3	18.6	13.8	18.6
Direction of max. wind* (deg.)	248	252	250	160	161	153	146	153	101	157	231	141	231
Average station pressure (hPa)	679.1	678.8	680.0	680.2	681.5	681.0	681.8	681.7	681.1	681.1	679.9	680.0	680.5
Maximum pressure* (hPa)	682.6	682.0	684.7	684.4	684.3	683.5	684.5	684.4	683.6	683.2	684.1	683.2	684.7
Minimum pressure* (hPa)	675.4	675.2	675.3	677.4	678.7	678.4	678.3	678.7	678.7	678.8	673.3	672.6	672.6
Average air temperature (°C)	5.6	4.2	4.7	4.1	5.7	7.5	7.0	7.5	7.3	6.9	6.3	4.6	6.0
Maximum temperature* (°C)	11.6	10.4	11.0	11.4	11.8	14.2	13.1	12.8	12.6	11.9	11.6	10.5	14.2
Minimum temperature* (°C)	-0.2	-0.4	-0.4	-0.8	1.2	2.6	2.1	3.3	1.7	2.8	2.1	-0.4	-0.8
Average dewpoint temperature (°C)	-21.9	-19.8	-15.2	-11.9	-10.7	-12.8	-9.6	-9.4	-10.3	-14.8	-17.5	-12.3	-13.8
Maximum dewpoint temperature (°C)	2.1	2.8	6.2	6.3	5.1	6.1	7.7	7.3	7.9	5.8	5.2	4.2	7.9
Minimum dewpoint temperature (°C)	-33.5	-30.7	-30.7	-30.4	-25.1	-23.9	-23.1	-25.2	-22.0	-26.9	-29.9	-30.2	-33.5
Precipitation (mm)	2	16	4	0	0	0	0	0	34	0	6	38	100
							Day						
Prevailing wind direction	WSW	NW	NW	NNW	NNW	NE	NE	NNW	NNW	SE	SE	SE	NNW
Average wind speed (m s^{-1})	6.2	4.4	4.4	2.7	3.3	3.5	4.1	3.5	3.2	4.1	5.5	5.3	4.2
Maximum wind speed* (m s^{-1})	14.1	13.1	10.5	12.1	14. 1	11.0	10.0	10.9	13.1	13.2	19.3	16.8	19.3
Direction of max. wind* (deg.)	236	255	257	188	156	148	120	146	134	160	247	156	247
Average station pressure (hPa)	679.0	678.8	680.1	680.2	681.7	681.1	681.9	681.9	681.1	681.0	679.9	679.9	680.6
Maximum pressure* (hPa)	682.5	682.2	684.8	684.2	683.9	683.8	684.3	684.6	683.5	683.6	683.8	684.0	684.8
Minimum pressure* (hPa)	674.6	675.1	675.5	677.4	678.7	678.7	678.8	678.8	678.8	678.5	674.0	671.5	671.5
Average air temperature (°C)	9.6	8.3	8.8	7.9	10.3	11.8	11.6	11.7	11.6	10.9	10.0	8.0	10.0
Maximum temperature* (°C)	17.0	13.7	15.8	13.8	15.7	17.5	17.3	17.3	16.8	17.5	16.3	14.9	17.5
Minimum temperature* (°C)	0.6	0.0	-0.2	0.0	2.8	4.3	3.8	4.4	2.5	2.6	1.9	0.2	-0.2
Average dewpoint temperature (°C)	-15.8	-14.5	-8.8	-4.1	-4.2	-4.4	-3.5	-3.0	-3.3	-7.0	-11.8	-8.6	-7.4
Maximum dewpoint temperature (°C)	6.2	4.0	8.4	7.6	7.1	7.4	8.9	8.6	9.0	7.5	7.3	6.5	9.0
Minimum dewpoint temperature (°C)	-33.3	-30.3	-29.5	-26.2	-23.9	-21.9	-21.7	-24.9	-20.7	-25.8	-28.6	-29.3	-33.3
Precipitation (mm)	2	15	7	18	10	13	28	6	43	2	8	77	229

Instrument heights: wind, 10.2 m; pressure, 3398.4 m (MSL); air temperature, 2.0 m; dewpoint temperature, 2.0 m. Wind and temperature instruments are on a tower 15 m southwest of the main building.

*Maximum and minimum values are hourly averages.

Table 1.11. SMO 2002 and 2003 Monthly Climate Summary

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
							2002						
Prevailing wind direction	E	N	WNW	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE
Average wind speed (m s^{-1})	4.4	5.6	4.3	5.1	6.9	9.0	7.5	8.2	9.1	8.1	5.2	5.6	6.6
Maximum wind speed* (m s^{-1})	14.5	14.5	15.1	15.3	13.6	17.2	17.7	17.9	17.4	15.5	13.3	13.5	17.9
Direction of max. wind* (deg.)	322	342	354	131	120	149	140	134	137	137	147	140	134
Average station pressure (hPa)	999.8	999.8	999.6	1000.4	1000.8	1002.2	1002.6	1001.8	1002.6	1000.9	999.7	998.6	1000.7
Maximum pressure* (hPa)	1003.5	1004.2	1004.8	1004.5	1006.0	1005.7	1006.6	1005.9	1005.8	1005.0	1004.9	1002.4	1006.6
Minimum pressure* (hPa)	995.8	993.0	994.5	996.7	994.6	998.4	998.8	997.9	999.3	995.6	993.5	994.6	993.0
Average air temperature (°C)	27.2	28.2	27.8	27.6	27.5	26.7	26.4	25.7	26.1	26.2	27.3	27.7	27.0
Maximum temperature* (°C)	29.1	29.0	29.4	29.1	28.7	28.0	28.3	27.7	27.4	28.1	29.1	29.7	29.7
Minimum temperature* (°C)	23.4	26.1	24.6	24.8	24.6	23.3	23.7	23.4	23.3	22.9	24.3	23.8	22.9
Average dewpoint temperature (°C)	21.8	24.0	24.7	24.6	24.4	23.2	23.5	22.7	23.9	24.1	25.7	24.7	24.1
Maximum dewpoint temperature (°C)	24.8	24.9	26.1	26.1	26.3	25.4	25.2	26.0	26.0	26.3	27.2	27.4	27.4
Minimum dewpoint Temperature (°C)	18.3	22.0	22.1	22.1	20.7	17.4	20.8	15.3	21.0	19.5	21.9	20.9	15.3
Precipitation (mm)	167	154	217	238	243	114	233	127	124	203	328	337	2485
							2003						
Prevailing wind Direction	NNW	SSE	SE	SE	SE	SSE	SE	SSE	SE	SE	SE	SE	SE
Average wind Speed (m s^{-1})	5.6	3.8	4.9	5.8	7.7	7.7	8.4	5.8	8.3	6.8	7.6	5.5	6.5
Maximum wind Speed* (m s^{-1})	13.9	14.0	15.7	12.8	19.1	16.0	15.4	12.8	15.2	13.3	17.3	13.7	19.1
Direction of max. Wind* (deg.)	319	280	349	311	128	151	140	144	134	139	122	138	128
Average station Pressure (hPa)	998.1	996.8	999.6	1000.3	1000.4	1002.2	1002.3	1002.2	1002.7	1001.7	1000.3	998.7	1000.5
Maximum pressure* (hPa)	1003.1	1002.3	1005.6	1005.4	1004.1	1006.1	1006.6	1006.1	1005.8	1005.3	1004.5	1003.3	1006.6
Minimum pressure* (hPa)	994.4	990.2	991.8	995.4	996.7	998.2	998.1	996.8	999.3	998.1	996.5	990.3	990.2
Average air Temperature (°C)	28.1	27.5	27.6	27.4	27.1	25.7	25.8	25.5	26.5	26.8	26.6	26.6	26.8
Maximum temperature* (°C)	29.6	29.7	28.9	28.8	28.3	27.3	27.3	27.6	27.9	28.3	28.0	28.3	29.7
Minimum temperature* (°C)	25.2	23.7	24.6	24.6	23.9	22.8	23.0	22.8	23.1	23.9	23.5	23.3	22.8
Average dewpoint temperature (°C)	25.2	24.4	24.7	24.6	24.6	22.5	24.0	22.8	22.6	23.0	23.5	24.2	23.9
Maximum dewpoint temperature (°C)	27.0	26.2	25.8	26.0	26.3	25.1	26.3	25.7	24.6	25.0	25.1	25.6	27.0
Minimum dewpoint temperature (°C)	22.4	21.2	22.5	22.4	20.9	17.4	18.5	17.6	19.3	19.7	21.2	21.2	17.4
Precipitation (mm)	284	242	171	149	182	124	88	139	53	97	337	368	2234

Instrument heights: wind, 13.7 m; pressure, 78.5 m (MSL); air temperature, 18.9 m; dewpoint temperature, 18.9 m. Wind and temperature instruments are on Lauagae Ridge, 110 m northeast of the main building.

*Maximum and minimum values are hourly averages.

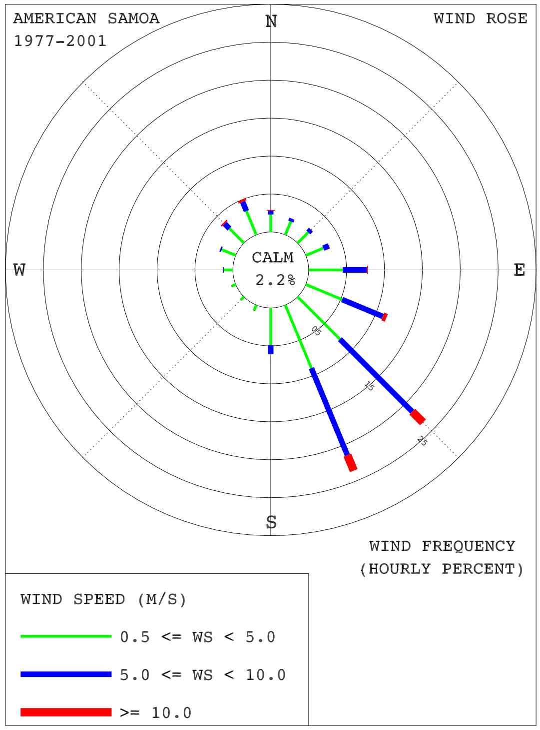
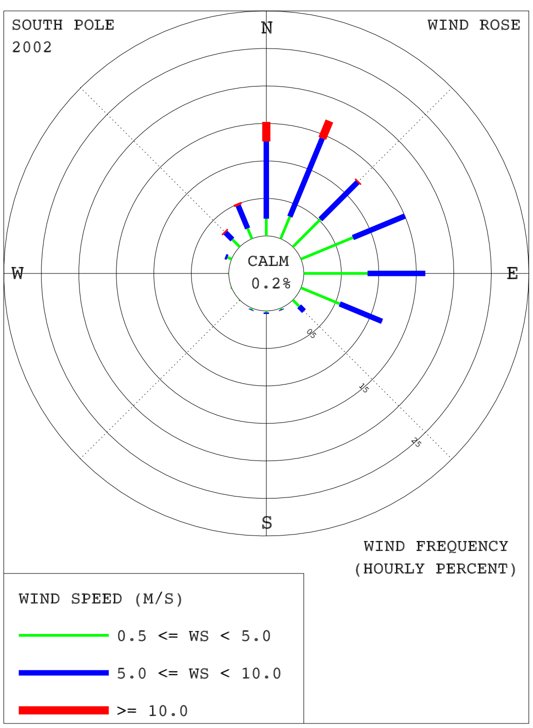


Figure 1.13. Wind rose of the surface winds at SMO for 1977-2001. The distributions of prevailing wind direction and speed are given in units of percent occurrence for the 25-year period for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graph.



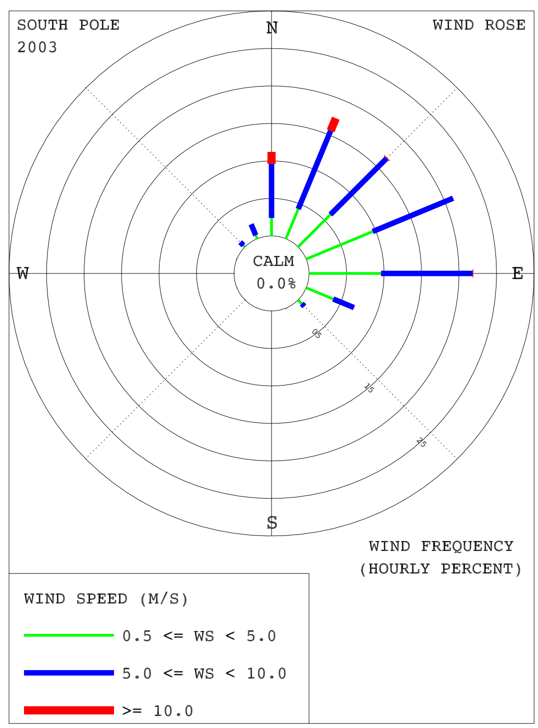


Figure 1.14. Wind roses of the surface winds at SPO for 2002 (left) and 2003 (right). The distributions of prevailing wind direction and speed are given in units of percent occurrence for 16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graphs.

Table 1.12. SPO 2002 and 2003 Monthly Climate Summary

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
							2002						
Prevailing wind direction	NNE	ENE	ENE	N	E	E	NNE	NNE	ESE	N	NE	E	NNE
Average wind speed (m s^{-1})	5.7	6.1	6.7	6.6	5.9	5.7	7.6	6.8	5.0	6.0	4.7	3.9	5.9
Maximum wind speed* (m s^{-1})	13.8	11.7	12.3	13.2	12.1	11.7	15.0	13.8	10.1	15.4	10.3	7.4	15.4
Direction of max. wind* (deg.)	9	8	321	7	27	13	17	16	29	357	95	354	357
Average station pressure (hPa)	686.6	681.2	684.7	679.4	687.9	676.9	680.0	668.9	679.3	685.4	678.7	681.1	680.5
Maximum pressure* (hPa)	697.1	694.7	695.7	694.4	705.4	693.1	698.0	688.3	688.8	703.9	700.4	690.7	705.4
Minimum pressure* (hPa)	674.4	669.4	671.5	667.9	671.4	659.9	666.8	657.2	670.8	672.9	667.6	671.0	657.2
Average air temperature (°C)	-26.1	-40.1	-49.4	-52.8	-56.3	-62.9	-53.4	-57.5	-56.8	-49.9	-39.4	-31.1	-47.6
Maximum temperature* (°C)	-14.1	-28.6	-30.4	-37.3	-33.8	-47.3	-40.5	-36.8	-32.5	-25.2	-23.4	-23.7	-14.1
Minimum temperature* (°C)	-38.2	-51.1	-65.7	-66.6	-66.9	-70.7	-72.0	-74.3	-68.6	-61.7	-47.0	-41.0	-74.3
Average dewpoint temperature (°C)	-29.0	-43.5	-52.4	-56.4	-59.8	-66.7	-56.9	-61.3	-60.4	-53.2	-43.1	-34.3	-51.0
Maximum dewpoint temperature (°C)	-15.9	-30.9	-32.8	-40.2	-36.2	-50.5	-42.8	-39.7	-35.3	-27.1	-26.1	-26.4	-15.9
Minimum dewpoint Temperature (°C)	-42.0	-55.3	-69.6	-71.1	-70.9	-75.4	-76.5	-78.7	-72.7	-65.0	-50.9	-44.6	-78.7
Precipitation (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0
							2003						
Prevailing wind Direction	ENE	ENE	E	ENE	E	E	NE	NNE	E	NNE	ENE	NNE	E
Average wind Speed (m s^{-1})	4.7	4.5	6.0	5.8	5.6	5.8	5.8	7.3	6.2	6.0	4.8	5.3	5.7
Maximum wind Speed* (m s^{-1})	10.3	9.5	10.7	11.8	11.6	11.2	10.9	15.0	13.1	13.8	10.9	10.5	15.0
Direction of max. Wind* (deg.)	82	66	2	13	3	14	20	13	7	8	5	3	13
Average station Pressure (hPa)	693.2	688.8	679.4	675.8	679.9	682.6	676.2	671.7	677.0	676.7	679.2	695.1	681.3
Maximum pressure* (hPa)	708.0	695.7	694.5	687.8	697.6	693.6	703.0	679.9	691.7	690.4	688.5	705.8	708.0
Minimum pressure* (hPa)	679.2	679.4	664.6	660.8	661.1	672.7	656.2	656.7	660.6	662.2	672.6	687.3	656.2
Average air Temperature (°C)	-27.8	-40.5	-54.1	-56.8	-59.3	-64.2	-64.0	-55.8	-61.7	-52.7	-39.2	-25.0	-50.2
Maximum temperature* (°C)	-20.4	-30.0	-34.2	-40.6	-44.5	-47.7	-46.6	-43.6	-43.3	-39.5	-30.7	-20.2	-20.2
Minimum temperature* (°C)	-34.4	-50.3	-65.2	-68.5	-71.7	-71.5	-73.4	-68.6	-73.4	-66.7	-49.4	-31.9	-73.4
Average dewpoint temperature (°C)	-31.0	-43.8	-57.6	-60.5	-62.9	-67.7	-67.8	-59.1	-65.1	-56.0	-42.6	-27.9	-53.5
Maximum dewpoint temperature (°C)	-23.5	-32.1	-37.1	-43.7	-47.8	-50.9	-49.3	-46.9	-46.0	-42.7	-33.3	-22.5	-22.5
Minimum dewpoint temperature (°C)	-37.8	-53.8	-69.2	-72.7	-75.9	-75.5	-77.7	-72.7	-77.0	-70.1	-52.8	-35.6	-77.7
Precipitation (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0

Instrument heights: wind, 10.0 m; pressure, 2841 m (MSL); air temperature, 2.0 m; dewpoint temperature, 2.0 m. Wind and temperature instruments are on a tower 91.4-m grid north-northwest of the Atmospheric Research Observatory.

*Maximum and minimum values are hourly averages.

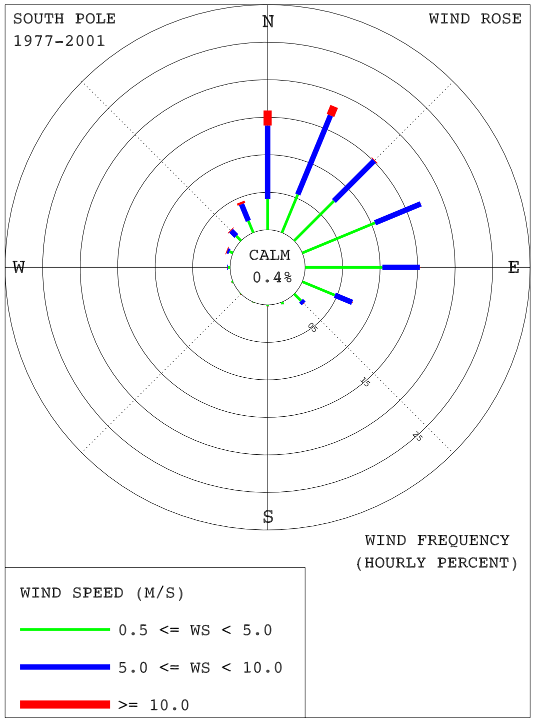


Figure 1.15. Wind rose of the surface winds at SPO for 1977-2001. The distributions of prevailing wind direction and speed are given in units of percent occurrence for the 25-year period for16 direction classes and 3 wind speed (WS) classes. Percent frequency of calm winds (WS < 0.5 m s^{-1}) is indicated on the graph.

97.6% in 2003, similar to the 25-year average of 93.7% (Figure 1.15). The percentage of winds in the 10 m s^{-1} or greater class was 5.8% in 2002 and 3.6% in 2003 while the long-term average is 4.0%. The annual average wind speeds for 2002 (5.9 m s^{-1}) and 2003 (5.7 m s^{-1}) were both higher than the long-term average wind speed of 5.4 m s^{-1}. January 2002 set a new high speed record of 13.8 m s^{-1}.

The average temperature for 2002 (–47.6°C) was warmer than the long-term average, whereas 2003 (–50.2°C) was colder than the long-term average of –49.3°C. December 2002 tied its minimum temperature for the month. The minimum temperature in 2002 of –74.3°C occurred in August. The minimum temperature in 2003 of –73.4°C occurred in July and September. The annual average barometric pressure for 2002 (680.5 hPa) was 1.3 hPa higher than the 25-year average of 679.2 hPa while the average barometric pressure for 2003 (681.3 hPa) was slightly above average.

Trinidad Head

Currently, the wind direction at Trinidad Head is measured by a R. M. Young wind vane attached to the aerosol sampling mast at a height of 9 m above the surface and by a second wind vane on the radiation tower at an elevation of 3 m above the surface. The wind-speed is recorded with Davis wind cups. These instruments have been in service for 2 years.

The CMDL Observatory Operations group is planning to deploy a complete set of meteorological instrumentation on Trinidad Head by 2005. The instrumentation will consist of Technical Services Laboratory sensors for ambient and dew point temperatures, an R. M. Young anemometer for wind direction and speed, a Setra pressure transducer for the barometric pressure, two aspirated platinum resistance probes for ambient temperature, and a precipitation gauge.

1.7. References

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