NDP 001a
ORNL/CDIAC-147

Atmospheric Carbon Dioxide Concentrations at 10 Locations Spanning Latitudes 82°N to 90°S

Contributed by

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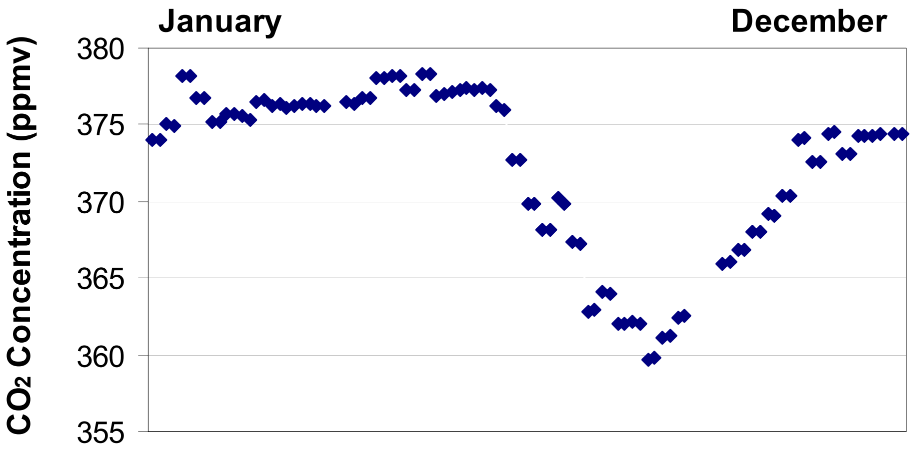
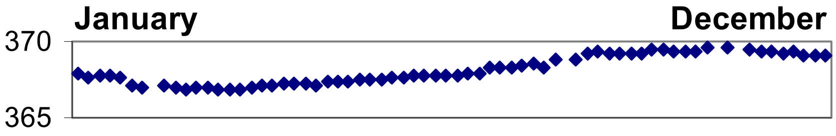
University of California, San Diego
La Jolla, California 92092-0244

CO_2 Concentrations for 2001

ALERT, NORTHWEST TERRITORIES, CANADA,
Latitude 82° 28' N



SOUTH POLE STATION
Latitude 89°59' S



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ACRONYMS AND ABBREVIATIONS

CDIAC	Carbon Dioxide Information Analysis Center
CO_2	carbon dioxide
IPCC	Intergovernmental Panel on Climate Change
NDP	Numeric Data Package
ORNL	Oak Ridge National Laboratory
ppm	parts per million (by volume, implied)
ppmv	parts per million by volume ("by volume" is specified)
reincl	Reincluded data initially flagged by cutoff criteria (see section 5)
sigma	standard error of data fit to spline curve
SIO	Scripps Institution of Oceanography, University of California, San Diego, California, U.S.A.

ABSTRACT

Keeling C.D. and T.P. Whorf. *Atmospheric Carbon Dioxide Concentrations at 10 Locations Spanning Latitudes 82°N to 90°S.* T.J. Blasing and Sonja Jones, editors, ORNL/CDIAC-147, NDP-001a. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, 30 pp.

The Carbon Dioxide Research Group, Scripps Institution of Oceanography, University of California, San Diego, has provided this data set, which includes long-term measurements of near-surface atmospheric CO_2 concentrations at 10 locations spanning latitudes 82°N to 90°S. Most of the data are based on replicated (collected at the same time and place) flask samples taken at intervals of approximately one week to one month and subsequently subjected to infrared analysis. Periods of record begin in various years, ranging from 1957 (for the South Pole station) to 1985 (for Alert, Canada), and all flask data records except for Christmas Island and Baring Head, New Zealand extend through year 2001. Christmas Island data end with August, 2001 and Baring Head data end with October 2001. Weekly averages of continuous data from Mauna Loa Observatory, Hawaii, are available back to March 1958. Similar weekly averages are also available for La Jolla, California, from November 1972 to October 1975, and for the South Pole from June 1960 to October 1963. At the South Pole, however, this "weekly" averaged data is usually based on only one day of continuous sampling, and only about 2 averages per month are given. Flask data from all stations include replicate measurements and flagged questionable data; thus, they differ from the usual presentations of CO_2 data (e.g., Keeling and Whorf, 2004) which are monthly averaged values fitted to curves as discussed by Keeling et al. (1989). Questionable data are flagged with asterisks; the user is accordingly advised to use caution in including them in analysis or in interpreting them without reference to the flag codes that provide the rationale for data rejections.

The data are available in 13 ASCII files: 10 files give the flask measurements corresponding to each of the 10 locations; 2 additional files, one for La Jolla and another for the South Pole, each give about three years of averages, derived from continuous samples, to represent the corresponding weekly averages; another file gives weekly averages of the continuous record since 1958 at Mauna Loa, Hawaii.

These long-term records of atmospheric CO_2 concentration complement the continuous records made by SIO, and also complement the long term flask records of the Climate Monitoring and Diagnostics Laboratory of the National Oceanic and Atmospheric Administration. All these data are useful for characterizing seasonal and geographical variations in atmospheric CO_2 over several years, and for assessing results of global carbon models. Flask data provide information about "instantaneous" departures from the hourly or multi-hourly averages derived from the continuous data, and at the same time serve as a quality check on those averages. Additionally, flask samples can be archived for future analyses as more refined measuring techniques become available. Temporal and geographical variations in the flask data are similar to those in the continuous data. Annual averages and amplitudes of the annual cycle of atmospheric CO_2 concentration both decrease from high northern latitudes to high southern latitudes. Peak annual CO_2 concentrations occur in spring, around May in mid latitudes of the Northern Hemisphere and September or October in mid latitudes in the Southern Hemisphere.

Key words: carbon dioxide, concentration, continuous data, flask data, Scripps Institution of Oceanography.

1. BACKGROUND INFORMATION

Carbon Dioxide (CO_2) is a "greenhouse" gas, that is, it absorbs infrared photons and re-emits them in all directions, including back towards the Earth's surface. This additional back-radiation, from all "greenhouse" gases combined, makes the surface-air temperature about 33ºC warmer than it would be in the absence of such radiation. Water vapor is the most effective "greenhouse" gas; CO_2 is next (Finlayson-Pitts and Pitts, 2000).

Fossil-fuel combustion adds CO_2 to the atmosphere, and it was recognized that this additional source might be contributing CO_2 faster than the oceans and terrestrial biosphere could remove it. If this were so, CO_2 would be accumulating in the atmosphere, leading to an increased amount of back radiation, and possibly to a warmer climate.

As early as the 1950s, Roger Revelle and some others were emphasizing the need to monitor temporal trends in atmospheric carbon dioxide (CO_2) at the global scale. Such monitoring requires measurements over a wide range of latitudes, at individual locations where local CO_2 concentrations are not influenced by nearby CO_2 sources or sinks (e.g., human activities or local vegetation).

Atmospheric CO_2 measurements were initiated at the South Pole and at the Mauna Loa Observatory, Hawaii, during the late 1950s. Later, additional stations were added, so that latitudinal coverage is now from the South Pole to 82.5º north. Continuous air sampling is done through pipelines; "grab" samples are also obtained and stored in flasks. This data package consists of raw flask data, including flagged data, and also includes some averages of continuous data for comparison. Processed monthly averages are also available from CDIAC (http://cdiac.esd.ornl.gov/trends/co2/sio-keel.htm) as another data package (NDP-001).

2. METHODS

Atmospheric CO_2 samples have been collected at approximately weekly to monthly intervals in 5-liter evacuated glass flasks at 10 locations spanning latitudes 82ºN to 90ºS (Figure 1), and returned to the Scripps Institution of Oceanography (SIO), where CO_2 concentrations have been determined using a nondispersive infrared gas analyzer manufactured by Applied Physics Corporation. The same type of gas analyzer has also been used in the field to make continuous measurements of CO_2 concentration at some of the stations, the best-known series being from Mauna Loa Observatory. Weekly averages derived from the continuous data at Mauna Loa are given for most weeks in the 44-year record. The Mauna Loa record constitutes the longest continuous record of atmospheric CO_2 in the world (beginning in March 1958), and has employed the same methods of measurement throughout the data record. This continuous data record, ultimately based on four measurements per hour atop intake lines on several towers, is based on steady periods of CO_2 of not less than six hours per day. If no such periods are available on a given day, then no data are used that day. About three years of similar data are summarized for two additional stations, La Jolla Pier and the South Pole. These data are summarized at La Jolla as weekly averages for most weeks from November 1972 through

October 1975, and at the South Pole from June 1960 through October 1963, although the averages derived for the South Pole are usually based on only one day of acceptable data. Further information, including measurements of standard gases for calibration purposes, rejection of unstable data (measurements indicating fluctuations too rapid to be attributed to changes in background levels), and analysis of effects of wind speed and direction on concentration measurements, is available in Pales and Keeling, 1965, Keeling et al., 1976; Keeling et al., 1989, Keeling et al., 1995, Keeling et al., 2002 (with appendix and addendum), and Guenther et al., 2002.

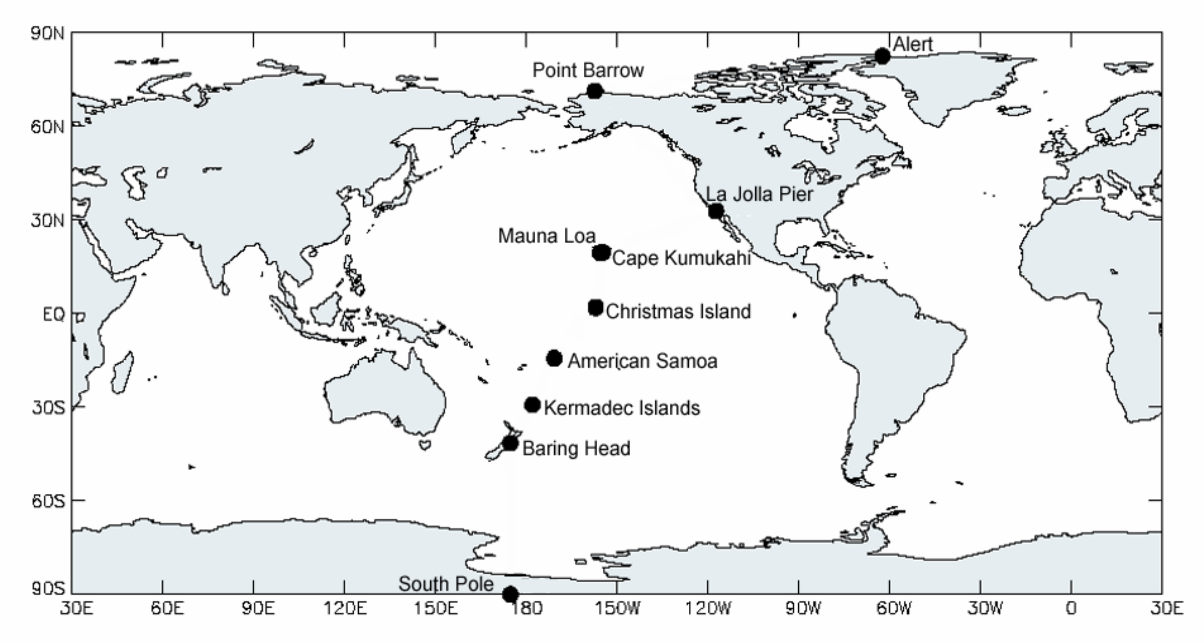

Figure 1. Map of CO_2 sampling sites included in this report.

3. TRENDS

Between 1958 and 2001, annual-average atmospheric CO_2 concentrations rose from about 315 parts per million by volume (ppmv), to about 369 ppmv at the South Pole and about 371 ppmv at Mauna Loa, Hawaii; these are the longest series of direct measurements available. Continuous data (NDP-001) are averaged at regular intervals (e.g., weekly or monthly) to provide long time series that are most appropriate to the study of long-term fluctuations. The flask data, presented here, are taken at irregular intervals and are therefore not as well suited to the study of long-term fluctuations. However, the flask data can serve as an independent check on the accuracy of the averages derived from continuous data, and flasks can be stored for later analyses after new measurement techniques are developed and become available. Differences between the "instantaneous" flask data and longer-term averages derived from continuous data can be useful in assessing the utility and value of "instantaneous" or "grab" samples taken where continuous data are not available. Flask data can also be used for some investigations of shorter term variations. Certain features of the data, including station-to-station differences in amplitude and phase of the annual cycle, are evident in the plots of annual series shown in Figure 2; shorter-term variations are also evident. Northern Hemisphere stations exhibit an annual cycle that is damped in the Southern Hemisphere, and very small at the South Pole where the annual range is only about 3 ppmv). This is related to the large terrestrial biosphere in the Northern Hemisphere, and the corresponding transfer of carbon from the atmosphere to plants during the growing season, so that phase peaks occur during the spring season in both hemispheres. Carbon dioxide increases in the Northern Hemisphere lead those in the Southern Hemisphere, which is also expected, given the large amounts of anthropogenic input in the Northern Hemisphere. The “preindustrial” (before year 1750) value of atmospheric carbon dioxide concentration was probably around 280 ppmv (IPCC, 2001, pp. 6-7).

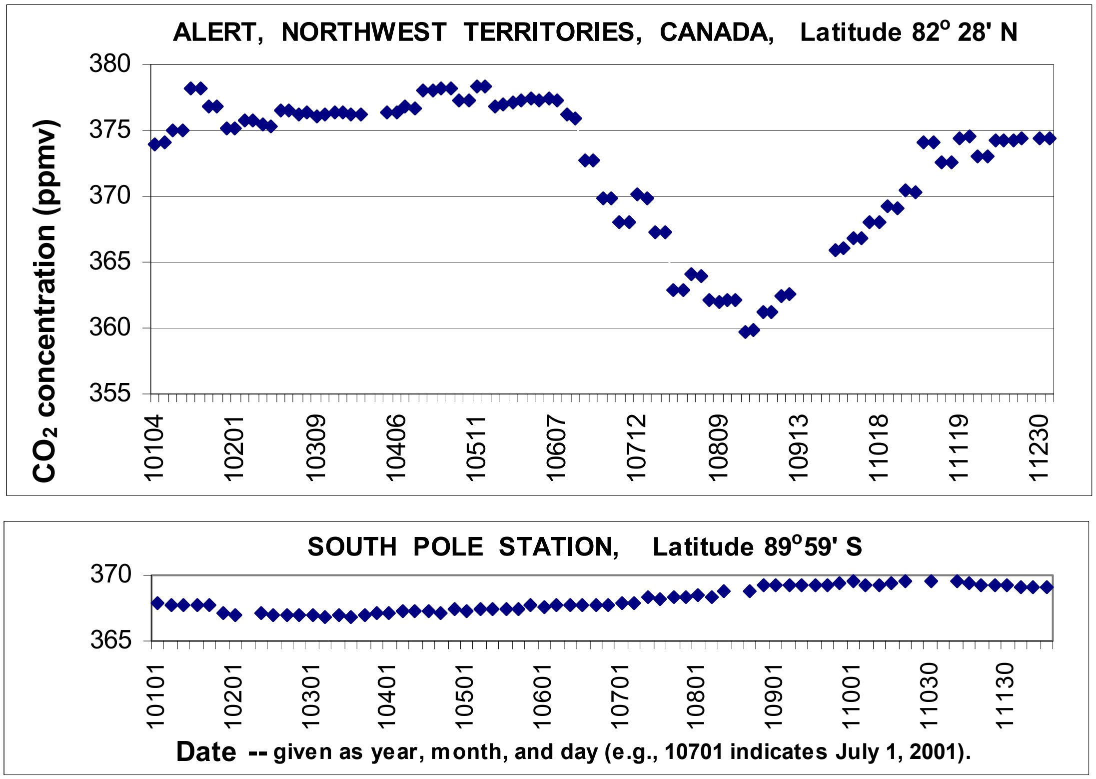

Figure 2. Comparison of the amplitude and phase of the annual cycle of atmospheric CO_2 concentration, in parts per million by volume (ppmv), at Alert, Canada and the South Pole. Annual ranges exceed 15 ppmv at high-latitude sites in the Northern Hemisphere, and decrease southward to about 3 ppmv at the south Pole. Phase peaks occur during the spring season, around May in the Northern Hemisphere and November in the Southern Hemisphere.

4. INFORMATION ABOUT THE DATA FILES

These data are available directly from CDIAC (http://cdiac.esd.ornl.gov/trends/co2/sio-keel-flask/sio-keel-flask.html). Electronic copies are maintained by T.J. Blasing and Sonja Jones.

The files contain sampling and analysis information for each glass flask sampled at each of the 10 SIO sampling sites, and later analyzed at SIO. The 10 sampling sites, in order of latitude from north to south, location (latitude and longitude), elevation above mean sea level (msl) and period of record at each site, are given in Table 1.

Further information regarding these sites is available in Keeling et al., 1986, and in *Trends 93, A Compendium of data on global change*, CDIAC, Oak Ridge National Laboratory. Additional files for two of these stations contain weekly averages derived from continuous data as follows: Mauna Loa (March 1958 – December 2001) and La Jolla Pier (November 1972 - October 1975). Another file includes one-day averages, as indicators of associated "weekly" averages, given roughly twice per month at the South Pole, from June 1960 - October 1963.

Table 1: Station codes, names, locations, and period of record for all stations included in this data package.

Code	Station	Latitude	Longitude	Elevation (m) above msl	Period covered
ALT	Alert, Canada	82ºN	62ºW	210	5/85 – 12/01
PTB	Point Barrow, Alaska	71.3ºN	157.3ºW	11	1/74 – 12/01
LJO	La Jolla Pier, California (flask data)	32.9ºN	117.2ºW	10	10/68 – 12/01
LJO	La Jolla Pier, California (continuous data)	32.9ºN	117.2ºW	10	11/72 – 10/75
MLO	Mauna Loa Observatory, Hawaii (flask data)	19.5ºN	155.6ºW	3397	3/60 – 12/01
MLO	Mauna Loa Observatory, Hawaii (weekly averages derived from continuous data)	19.5ºN	155.6ºW	3397	3/58 – 12/01
KUM	Cape Kumukahi, Hawaii	19.5ºN	154.8ºW	3	3/79 – 12/01
CHR	Christmas Island (Kiribati)	2ºN	157.3ºW	3	12/74 – 8/01
SAM	Cape Matatula, American Samoa	14.3ºS	170.7ºW	30	9/81 –12/01
KER	Kermadec Islands (Raoul Is.)	29.2ºS	177.9ºW	2	12/82 –12/01
NZD	Baring Head, New Zealand	41.4ºS	174.9ºE	85	7/77 – 10/01
SPO	South Pole station (flask data)	90ºS	0ºW	2810	5/57 – 12/01
SPO	South Pole Station (continuous data)	90ºS	0ºW	2810	6/60 – 10/63

The general format for files containing flask data is one line for each flask sample. Column headings are described in Table 2.

Field sheets and analysis sheets for flask data are stored at SIO.

The j scale and x99 scale are described more completely in Keeling et al., 2002.

The files containing averages of continuous measurements over periods of a week at La Jolla and Mauna Loa, and one-day averages at approximately semi-monthly intervals at the South Pole, consist of five columns, with the first column showing the station code, followed by the sampling date, the number of days included in the sample, a space reserved for the flag code (usually = 0, accepted continuous data) and finally, the temporally averaged CO_2 concentration (ppmv) in the fifth column. The sampling dates given at La Jolla and Mauna Loa are the central days of the respective, 7-day, sampling periods.

Station observers and their 2 or 3-letter codes are listed alphabetically by last name in Appendix B for each station for the entire period of operation. Some observers are listed by two codes and have the words "also as" following their names with the second code immediately following the first. For a few codes, names not known are left blank in the observer list. Also the code "U" has been occasionally used for name unknown.

Table 2. Description of column-heading codes.

Heading	Description
Station	Station code (3 letters), as per Table 1.
Flask ID	Flask identification number (5 characters).
Flask size	Flask volume in liters, generally = 5.
Sample date/time	Year, month, day (yymmdd) and local military time in hours and minutes (hhmm).
Latitude and Longitude	Latitude (5 characters) and longitude (6 characters) of station in degrees.
Observer	Observer code (up to 3 characters); names of observers and matching codes are given in Table A-1.
Analysis date	Date the sample was analyzed.
X99	Atmospheric CO_2 (ppmv) in the 1999 calibration scale (Keeling et al., 2002); an asterisk indicates data that did not meet the cutoff criteria described in the text.
Field sheet number	Field sheet numbers are 3 characters, maximum is 999 and then the sequence starts again.
Analysis sheet number	Analysis sheet number.
J scale	An intermediate scale for concentration, related to the infrared analyzer response (see Keeling et al., 2002); an asterisk indicates data that did not meet the cutoff criteria described in the text.
Sample date	The sample date is repeated.
Weight	Weighting is 1 for each flask; when used in weekly averaged continuous data, it is the number of days included (1 character).
Flag code	One number; flag codes are described in Table 3, Section 5, below.
x99	Repeat of the concentration, in the 1999 calibration scale, but without flagging asterisks.
Comment	Additional comments (e.g., unsteady air).

5. DATA CHECKING AND DEFINITIONS OF FLAG CODES

Primary flask data selection was made automatically using a "standard cutoff flag." Flask air samples are typically taken in pairs to confirm if the air was steady in concentration. If the pair difference was greater than a given amount, termed the "cutoff value," then both flasks were flagged. If more than two flasks were taken, then any flasks within this cutoff amount of the lowest flask were accepted. Single-flask (unreplicated) samples were rejected. For all but two stations the cutoff value is 0.40 ppmv. The two stations using slightly higher cutoff values in order to retain more of the data, are at the Kermadec Islands (0.50 ppmv) and Barrow, Alaska (0.60 ppmv).

Secondary flags were later applied using the procedures and codes listed in Table 3. Codes 0 and 1 are the only codes for accepted data.

A small number of flask data (about 65 flasks, or 0.2%) initially rejected by cutoff criteria were accepted upon closer scrutiny, a third of them during the early South Pole data period (1957 - 1959) when there were many singlets, another third at Christmas Island between

1996 and 2001, with most of the remainder at New Zealand. These reincluded data are annotated under the comment heading as "reincl" (for pairs, the pair difference is noted as = dif, singlets are noted as sglt). The amount of data rejected by the 3-sigma criterion (see code 5, Table 3) amounted to about 4.5% of all flasks taken and was the second most widely used flag after the cutoff flag. Finally, in the early years of the longest records (during the 1950's and 1960's), the 3-sigma flag was also used in a few cases as a preemptory flag.

Data checking at CDIAC routinely begins with plotting time-series graphs of the data as received. The flask data showed more short-term fluctuations than did averages of continuous data, but the differences were consistent with differences between “grab” samples and longer-term averages, and were therefore deemed to primarily represent information, as opposed to noise. The quality checks performed by the contributors, as discussed above, appear to have either eliminated or flagged all questionable data.

Table 3. Secondary flag codes.

Code	Interpretation
0	Accepted continuous data
1	Accepted flask data
2	Rejected: unacceptably large flask-analyzer differences associated with night sampling (used only at MLO between December 1962 and September 1968)
3	Rejected: used continuous data instead (used only at SPO between June 1960 and October1963)
4	Rejected: by standard cutoff flag for each station
5	Rejected: greater than +/- 3 standard deviations from a fitted spline curve which contains a 4-harmonic seasonal term and a seasonal gain factor (see Keeling et al., 1989)
6	Rejected to improve local distribution of data, such as too many data of generally poor quality (used only at two stations: Cape Kumakahi, Hawaii from August 1979 - June 1980, and La Jolla California from April 1979 - September 1985)
7	Rejected: unsteady air at the site and not rejected by other means (used only at La Jolla in less than 1% of the flasks)

6. ACKNOWLEDGEMENTS

Many personnel from other groups have contributed over the years so that sampling of atmospheric CO_2 at these 10 stations has not been interrupted. The Scripps Institution of Oceanography wishes to acknowledge the primary contributors as:

NOAA Climate Monitoring and Diagnostics Laboratory, Cooperative Air Sampling Network, Boulder, Colorado
Mauna Loa Observatory personnel and the CO_2 Measurement Program, Hilo, Hawaii
The Canadian Atmospheric CO_2 Measurement Program, Greenhouse Gases Measurement Laboratory Meteorological Service of Canada, Toronto, Ontario, Canada
The National Institute of Water & Atmospheric Research, Wellington, New Zealand

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8. LINK TO ADDITIONAL PUBLICATIONS

For additional information on the Scripps Institution of Oceanography reference gas calibration system, and access to journal articles arising therefrom, go to: Scripps Reference Gas Calibration System for Carbon Dioxide-in-Nitrogen and Carbon Dioxide-in-Air Standards: Revision of 1999 (with Addendum).

APPENDIX A. DIAGRAM OF THE CONSTANT-VOLUME MERCURY MANOMETER

The constant-volume mercury manometer diagram can also be obtained online at:

http://cdrg.ucsd.edu/articles.html/GasCalibrations/

Figure A-1 (next page). Diagram of the constant-volume mercury-column manometer (CMM), constructed in 1958 of pyrex glass. There are twin small volume manometers on the left and one large volume manometer on the right. All three units have multiple chambers. When these are not in operation, mercury fills all columns below the level shown. Elements shown by dashed lines lie behind solid-line elements. Sample gas is introduced through any of five tubes shown at the top, controlled by stopcocks just below. Chamber volumes for the small manometers are defined by pointers to which mercury is forced to just make contact by exerting pressure on ballast chambers (shown by dashed lines) connected to a remote source of gas pressure.

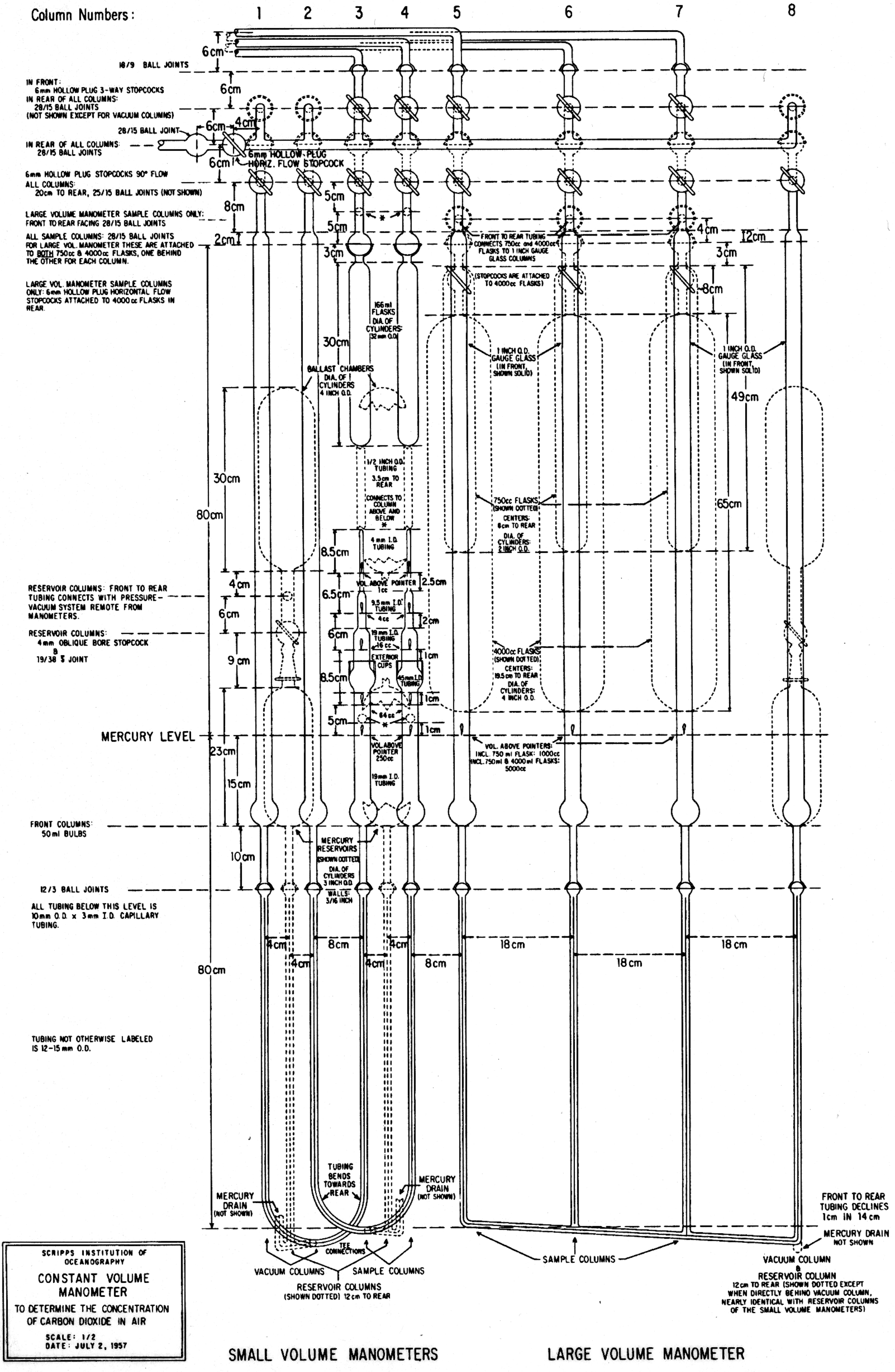

Figure A-1. Diagram of the constant-volume mercury manometer

APPENDIX B

LIST OF OBSERVERS AND OBSERVER CODES FOR ALL 10 STATIONS:

ATMOSPHERIC CO_2 DATA SET – SCRIPPS INSTITUTION OF OCEANOGRAPHY

OBSERVERS AND OBSERVER CODES FOR ALERT, NORTHWEST TERRITIRIES, CANADA

AD	A. DENIS	
AL	AARON LAWRENCE	
AP	A. PLATT	
BB	BUCK BUKOSKI	ALSO AS BU
BH	BRYAN HURREN	
BS	B. SARGENT	
BU	BUCK BUKOSKI,	ALSO AS BB
CH	CRAIG HAWTHORNE	
CL	CLEE LIEVERSE	
CP	C. PILLER	
DA	SUZANNE D'AMOURS	
DAE	DARRELL ERNST	
DE	DEVEAU	
DW	DOUG WORTHY	
ET	ERIN TAIT	
GJ	G. JAMES	
GL	GAVIN LAW	
GP	G. PELLAND	
GRS	GRANT SCHOLES	
GS	GREG STANSFIELD	
HE	HARRY EWEN	
JM	J. MCNAIRN	
KA	KEVIN ANDERSON	
KB	KORB WHALE	
KMG	K.M. GAIDER	
KR	KRAWIT	
KS	KRIS SHELSWELL	
LA	LAUREEN	
LF	LARRY FLYSAK	
LL	LORI LEEDER	
LO	L. OATWAY	
MB	M.J. BYATT	
MD	M. DOUCETTE	
MG	MAURICE GOETHALS	
MM	MITCH MATSZEL	
MR	MICHELE RAUH	
MS	MURRAY SMITH	
NS	NEMAN SYED	
NT	DR. NEIL TRIVETT	
PA	PETER AYRANTO	
PB	PATRICK BRAUER	
PC	P. CHOMIK	
PSG	PAUL GERLA	
RFK	RALPH KEELING	

OBSERVERS AND OBSERVER CODES FOR ALERT, NORTHWEST TERRITORIES, CANADA (CONTINUED)

RN	REBECCA NG
RV	R. VAN BRABANT
SH	SCHROEDER
SI	SYED IQBAL
SM	S. MERCER
SO	SHAWN OGSTON
SS	STACY SYMINGTON
TB	T. BIESENTHAL
TG	TED GRESIUK
TS	TINA SCHERZ
U	UNKNOWN
VC	VALERIE CHORNEY
VH	VICTORIA HUDEC
VM	ADRIAN VAN de MOSSELAER
VV	VIRCE VOURA
WD	WAYNE DAVIDSON
WEB	WEBSTER

OBSERVERS AND OBSERVER CODES FOR POINT BARROW, ALASKA, U.S.A.

AC	ANDY CLARK	
BA	KEN BAUER	
BCH	BRAD HALTER	ALSO AS BH
BD	BOB DRURY	
BH	BRAD HALTER	ALSO AS BCH
BJT	BRUCE J. TIESKE	
CG	CARL GROENEVELD	
CLC	CHRISTOPHER CHURYLO	
CM	CHARLES MCISAAC	
DE	DAN ENDRES	
DG	DAVID GAINES	
DMT	DALE TYSOR	
DMW	DANIEL M. WILLIAMSON	
DS	DAVID SMITH	
DTB	DESMOND T. BAILEY	
DWB	D. W. BEARD	
EC	ELIZABETH CROZER	
ES	ERIC SANDBERG	
ESH	E. STEVEN HILL	
EW	EMERSON WOOD	
GF	GEORGE FAUST, JR.	
GMC	GLEN MCCONVILLE	
GY	GERALD YUNG	
HI	HISCOX	
JCO	JEFF OTTEN	
JDU	JOHN D. UNGER	
JIM	JIM WENDELL	ALSO AS JW
JJ	JIM JORDAN	

OBSERVERS AND OBSERVER CODES FOR POINT BARROW, ALASKA, U.S.A. (CONTINUED)

JJK	JOHN J. KELLEY	
JTM	JOEL MICHALSKI	
JW	JIM WENDELL	ALSO AS JIM
KMC	KATE MCNITT	
LAS	LEANDER A. STROSCHEIN	
LW	LARRY WESTERMAN	
MAW	MARK WINEY	
MGG	MALCOM GAYLORD	
MJB	MARK BOLAND	
MSO	MIKE O'NEILL	
NH	NATHAN HILL	
PD	PAUL DIX	
POR	PAULINE ROBERTS	
PRS	RICARDO RAMOS	ALSO AS RR
RAW	ROGER A. C. WILLIAMS	
RF	RANDY FOX	
RJT		
RLH	RONNIE L. HAMBY	
RR	RICARDO RAMOS	ALSO AS PRS
SF	S. FAHNENSTIEL	
TDF	THOMAS E. DEFOOR	
TH	TOM HARRIS	
TQ	TIM QUACKENBUSH	
TRJ	THOMAS JACOBS	
TW	TIM WOLFE	
U	UNKNOWN	

OBSERVERS AND OBSERVER CODES FOR LA JOLLA, CALIFORNIA, U.S.A.

A	ANDRE	
AB	ARNOLD BAINBRIDGE	ALSO AS AEB
AEB	ARNOLD BAINBRIDGE	ALSO AS AB
AH	ART HESTER	
ALB	ALANE BOLLENBACHER	
ALH	ALANE HERRON	
BH	BRAD HALTER	
BH	BILL HISCOX	
BW	BRUCE WEBSTER	
BWC	BLANCHE W. CHRISTMAN	
CAB	CRAIG A. BURKE	
CAE	CARL A. EKDAHL	
CB	CRAIG BROWN	
CDK	CHARLES D. KEELING	
CG	CARL GROENEVELD	
CM	CINDY MCFEE	
CSW	C. S. WONG	

OBSERVERS AND OBSERVER CODES FOR LA JOLLA, CALIFORNIA, U.S.A. (CONTINUED)

CW	CHARLES WHITE	
DB	DAVE BOS	
DC	DICK CASEY	
DCL	DAVID C. LOWE	
DG	DAVID GOHEEN	
DHW	DAVE H. WIEDERSPAHN	
DJM	DAVID MOSS	ALSO AS DM
DJW	DENIS J. WALTS	
DM	DAN MILDER	
DM	DAVID MOSS	ALSO AS DJM
DP	D. PHLEGER	
DRM	DAVID R. MUDGETT	
DWN	DON NELSON	
EAC	ELIZABETH CROZER	
EAJ	ED JESSUP	
ED	ED DLUGOKENCKY	
EJS	ED SLATER	
EKB	ERYC BRANHAM	
EMW	EUGENE M. WILKINS	
ES	ELAINE SNYDER	
FM	F. MANLEY	
FM	FRANK MIGAIOLO	
FS	FRANK SANCHEZ	
GC	GLEN CALTA	ALSO AS GMC
GMC	GLEN CALTA	ALSO AS GC
GN	GUY NUSHOLTZ	
HC	H. COLEMAN	
HE	HAROLD EMERY	
JAA	J. ALEXANDER ADAMS, JR.	
JAK	JOHN A. KERBER	
JCB	JOHN C. BORTNIAK	
JCO	JOHN C. OSBORNE	
JGS	JOSEPH G. STRAUCH, JR.	
JHJ	JOHN H. JENNINGS	
JJ	JOHN JAIN	
JJ	JO JOHNSON	
JJB	JIM BARRY	
JK	JIM KIRCHHOFFER	
JL	JUSTIN LANCASTER	
JM	JOHN MCPHERREN	
JRK	J. R. KROTH	
JS	J. SCARLETT	
JS	JOHN SHAY	ALSO AS JTS
JTS	JOHN SHAY	ALSO AS JS
JW	JAMES WADDELL	
JW	JIM WELLS	
JY	JASON YANG	
KBM	KEN MARMENT	
KP	KATIE PIPER	ALSO AS KWP
KWP	KATIE PIPER	ALSO AS KP

OBSERVERS AND OBSERVER CODES FOR LA JOLLA, CALIFORNIA, U.S.A. (CONTINUED)

LCG	LYDA C. GATEWOOD	
LFG	L. F. GILLESPIE	
LOW	SHERRI LOWE	
LSW	LEE S. WATERMAN	
MAJ	MIKE JONES	
MAS	MIKE SHULSINGER	
MF	M. FIELDS	
MG	MIKE GRINNELL	
MH	MARTIN HEIMANN	
ML	M. LEBER	
MSF	MARY SUE FIGEL	
MW	MARK WINEY	
NJP	NANCY J. PHILLIPS	
NT	NEIL TRIVITT	
PC	PAULA CRABBE	
PP	PETER POHL	
PPT	PIETER TANS	
PRG	PETER R. GUENTHER	
PS	PAUL SWEET	
RA	RANDALL ALLEN	
RAA	ROBERT A. AVCHEN	
RB	RUSSEL BRAINARD	
RG	RICHARD GOTTHOFFER	
RGW	ROBERT WILLISCROFT	
RH	RICHARD HART	
RJ	RICK JANKE	
RJ	RUSS JOHNSON	
RJL	RAY J. LAGOMARSINO	
RKM	RON MCINNES	
RL	RICHARD LOTTE	
RP	RON PATRICK	
RRP	ROB POSTON	
RS	RON STEPHEN	
RVW	RICK VAN WOY	ALSO AS VW
RW	RAY WEISS	
RW	ROBERT WILLIAMS	
RW	R. WITALIS	
SDL	STAR LANCASTER	
SK	LT. STEVE KOTT	
SK	SCOTT KUESTER	
SP	STEVE PIPER	
SW	STEVEN WHY	
TAV	TAM VOYNICK	
TBH	THOMAS B. HARRIS	
TC	TOM CONWAY	
TJ	TERRI JACKSON	
TL	TIM LEUKER	
TN	TAKAKIO NAKAZAWA	
TN	T. NASTOS	
TO	TOMINIKO	

OBSERVERS AND OBSERVER CODES FOR LA JOLLA, CALIFORNIA, U.S.A. (CONTINUED)

TPW	TIMOTHY WHORF	ALSO AS TW
TW	TIMOTHY WHORF	ALSO AS TPW
VS	VAL SZWARC	
VW	RICK VAN WOY	ALSO AS RVW
WCB	WILLIAM BOLLENBACHER	
WM	WIM MOOK	
WP	SKIP PRICE	

OBSERVERS AND OBSERVER CODES FOR MAUNA LOA OBSERVATORY, HAWAII

AA	A. AUSTRING	
AY	ALAN YOSHINAGA	
BB	BARRY BODHAINE	
BL	BEN LEBLANC	
CC	CHARLES H. COOKE	
CK	CLIFFORD M. KUTAKA	
CM	CINDY MCFEE	
DK	CHARLES D. KEELING	
DM	DAVID MOSS	
FC	JOHN F. S. CHIN	ALSO AS FSC
FSC	JOHN F. S. CHIN	ALSO AS FC
HA	H. ARASHIRO	
HE	HOWARD ELLIS	
JAA	J. ALEXANDER ADAMS, JR.	
JCB	JOHN C. BORTNIAK	
JCP	JACK C. PALES	ALSO AS JP
JP	JACK C. PALES	ALSO AS JCP
MG	MARK GOLDMAN	
MK	F. M. KEYES	
PRG	PETER R. GUENTHER	
RCP	RONALD C. PRIEBE	ALSO AS RP
RJ	R. S. JACKSON	
RO	RYOSEI OSHIRO	
RP	RONALD C. PRIEBE	ALSO AS RCP
SR	STEVE RYAN	
VR	VERN RUMBLE	

OBSERVERS AND OBSERVER CODES FOR CAPE KUMUKAHI, HAWAII

AA	ARNE AUSTRING	
AMH	ALEEDA M. HANSON	
CM	CINDY MCFEE	
CO	K. COLSON	
DM	DAVE MOSS	
FSC	JOHN F. S. CHIN	
KR	F. KRANTZ	
LMP	LISA MCPHERSON	ALSO AS PH
MA	STEPHEN MATHEWS	
PH	LISA MCPHERSON	ALSO AS LMP

OBSERVERS AND OBSERVER CODES FOR CAPE KUMUKAHI, HAWAII (CONTINUED)

SR	STEVE RYAN
TW	TIMOTHY WHORF

OBSERVERS AND OBSERVER CODES FOR CHRISTMAS ISLAND (KIRIBATI)

AB	ANDREW BRYDEN	
AC	A. CATTELL	
AK	AMBO KEEBA	
BAR	BARANIKO	
BR	B. RAOBATI	
DC	DAVID CREAR	
DM	DAVE MOSS	
EL	ERUA TEKABARA	ALSO AS ET
ET	ERUA TEKABARA	ALSO AS EL
GK	GEORGE KRASNICK	
IT	ITIMAROROA TIRORA	
JAA	J. ALEXANDER ADAMS, JR.	
JB	JOHN BRYDEN	ALSO AS JMB
JMB	JOHN BRYDEN	ALSO AS JB
MAV	MARK VAUGHN	
PW	PHIL WILDER	
RS	R. SIXBERRY	
TA	TAKAEANG	
TI	TIAONI (JOHNNY) TARAWA	
WW	WILLIAM WILDER (PHIL'S GRANDSON)	

OBSERVERS AND OBSERVER CODES FOR AMERICAN SAMOA

AIB	
DE	DAN ENDRES
DEH	DOUG HOLT
DHN	DON NEFF
DN	DON NELSON
DT	
EE	ERIC SANDBERG
EWG	EMILY WILSON GODINET
GMC	GLEN MCCONVILLE
GY	GERRY YOUNG
JCF	J. FARMER
JTM	JOEL MICHALSKI
MEW	M. EMILY WILSON
MGG	MALCOM GAYLORD
MW	MARK WINEY
POR	PAULINE ROBERTS
PRG	PETER GUENTHER
RW	ROGER A.C. WILLIAMS
SR	STEVE RYAN
TOM	TED MULLEN
U	UNKNOWN

OBSERVERS AND OBSERVER CODES FOR KERMADEC ISLANDS (RAOUL ISLAND)

AP	AARON PICKERING
DE	DEREK
GH	GRANT HARPER
GP	GARTH PAUL
HAT	P. HATFIELD
HB	HERM BINNIE
IB	IAN BOYD
KA	KEVIN M. ALDER
KB	KATE BOWES
KO	KAREN OLSEN
KS	KEITH SPRINGER
LB	LESTER BRIDOA
MA	MIKE AMBROSE
MR	MARION RHODES
PB	PAUL BOWERING
PC	PHIL CLERKE
PF	PETER FISHER
PN	P. NGAMON
PT	PHILLIP TISCH
RBC	ROB CROWLEY
RC	RICHARD CONNOLLY
RH	ROB HAMILTON
ROC	ROSS CARROLL
RVM	RON VAN MIERLO
SC	STUART COCKBURN
SF	STEVE FLYNN
SK	STEVE KNOWLES
SU	SIMON UREN
TO	TRISH O'CALLAGHAN

OBSERVERS AND OBSERVER CODES FOR BARING HEAD, NEW ZEALAND

AB	A. BROMLEY	
AG	ANTHONY GOMEZ	
BT	BILL TROMPETTER	
BU	BILL USSLER	
CB	C. BRENNINKMEIJER	
CTN	COLIN T. NANKIVELL	
DCL	DAVE LOWE	ALSO AS DL
DF	DIMINIC FERRETTI	
DL	DAVE LOWE	ALSO AS DCL
ED	ED DLUGOKENCKY	
GB	GORDON BRAILSFORD	
GD	GREG DRUMMOND	
GLL	G.L. LYRE	
IH	IAN HEMMINGSON	
IK	I. KENNINGER	
JC	JILL CAINEY	
JM	JOHN MAR	
JO	JULIAN ORANGE	

OBSERVERS AND OBSERVER CODES FOR BARING HEAD, NEW ZEALAND (CONTINUED)

JR	JERRAM ROBINSON
KBM	K. B. MARMENT
LW	L. WALKER
MM	MARTIN MANNING
MN	MARGARET NORRIS
MRM	ROSS MARTIN
NRH	NIOLA REDVES HIGGINS
PH	P. HATFIELD
PP	PETER POHL
PR	PAUL ROBERTS
RM	ROWENA MOSS
SN	SYLVIA NICHOL
SO	STEVE O. NEILL
TB	TONY BROMLEY

OBSERVERS AND OBSERVER CODES FOR THE SOUTH POLE STATION, ANTARCTICA

BH	BRAD HALTER	
BW	BRUCE WEBSTER	
CAG	CHARLES GADSDEN	ALSO AS CG
CB	CRAIG BROWN	
CG	CHARLES GADSDEN	ALSO AS CAG
CLG	CARL GROENEVELD	
CM	CINDY MCFEE	
CW	C. WILSON	
DDG	DAVID GAINES	
DE	DAN ENDRES	
DHN	DON NEFF	
DT	DALE TYSOR	
DW	DENIS WALTS	
DWN	DON NELSON	
EAC	ELIZABETH CROZER	
EAJ	ED JESSUP	
EF	E. FLOWERS	
GE	GEORGE ENGEMAN	
HC	HAROLD L. COLEMAN	ALSO AS HLC
HH	H. HANSEN	
HLC	HAROLD L. COLEMAN	ALSO AS HC
HR	HOWARD REDIFER	
HT	HARRY THOMAS	
JB	JOHN BORTNIAK	ALSO AS JCB
JCB	JOHN BORTNIAK	ALSO AS JB
JCO	JEFF OTTEN	
JOL	JOHN LOWELL	
JP	JOHN C. PLANKINTON	
JRJ	JAMES R. JORDAN	
JRK	JAMES R. KROTH	
JTM	JOEL MICHALSKI	
JW	JIM WENDELL	
KJH	K. J. HANSON	

OBSERVERS AND OBSERVER CODES FOR THE SOUTH POLE STATION, ANTARCTICA (CONTINUED)

KM	KATE MCNITT
LA	L. ALDAZ
LG	L. F. GILLESPIE
MB	MARK BOLAND
MG	MALCOLM GAYLORD
MIG	FRANK MIGAIOLO
MON	MIKE O'NEILL
MVR	M. VANDERIET
MW	MARK WINEY
NH	NATHAN HILL
POR	PAULINE ROBERTS
RB	RUSSEL BRAINARD
RGM	RICHARD G. MAESTAS
RGW	ROBERT WILLISCROFT
RR	RICARDO RAMOS
RS	RON STEPHEN
RW	R. WITALIS
RWP	ROB POSTON
SJK	STEPHEN J. KOTT
SKU	SCOTT KUESTER
TJ	TOM JACOBS
VS	VALENTINE SZWARC
WAD	JAMES WADDELL, JR.
WH	WILLIAM HISCOX