ORNL/CDIAC-126

Fiscal Year 1999 Annual Report

Carbon Dioxide Information Analysis Center
World Data Center for Atmospheric Trace Gases

Environmental Sciences Division
Oak Ridge National Laboratory

March 2000

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Carbon Dioxide Information Analysis Center and World Data Center for Atmospheric Trace Gases

Fiscal Year 1999 Annual Report

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From the Director's Desk

Fiscal Year 1999 was a busy and productive one for the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory (ORNL). This report summarizes quite a few new and updated data and information products, and the "What's Coming in FY 2000" section describes our plans for the first fiscal year in the third millennium (or the final fiscal year of the second millennium, depending on how you feel about this issue).

In addition to the "core" CDIAC activities, such as quality-assuring and documenting databases on such global-change topics as emissions and atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases, and long-term climate records, this report contains a new section to highlight four special "focus areas": AmeriFlux, Free-Air CO_2 Enrichment (FACE), NARSTO, and Ocean Data.

CDIAC's continued its effort in data management for AmeriFlux, the long-term study of carbon fluxes between the terrestrial biosphere of the Western Hemisphere and the atmosphere. Tom Boden took over the reins (following Antoinette Brenkert's move to Washington, D.C., and her departure from CDIAC), assisted by Susan Holladay. Please visit CDIAC's AmeriFlux home page (http//cdiac.esd.ornl.gov/programs/ameriflux/); also note the discussion of CDIAC's AmeriFlux activities in the "Focus Areas" section in this annual report. Tom also prepared several new and updated databases in CDIAC's traditional area of greenhouse-gas emissions and atmospheric concentrations, such as the fossil-fuel CO_2 emissions database, which he and Gregg Marland maintain (http://cdiac.esd.ornl.gov/ trends/emis/em_cont.htm); the famous Keeling Mauna Loa CO_2 data (http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm); and the global, multi-investigator, ALE/GAGE/AGAGE database of trace gases (http://cdiac.esd.ornl.gov/ndps/alegage.html).

During FY 1999, CDIAC began a focus on FACE (Free-Air Carbon Dioxide Enrichment), the most sophisticated experimental approach to date for studying the effects of elevated CO_2 on vegetation. CDIAC's new FACE home page (http://cdiac.esd.ornl.gov/programs/FACE/face.html) begins the process of integrating the thirty-something FACE sites around the world. In collaboration with researchers at The Ohio State University, CDIAC also published numeric data packages that bring together results from many published CO_2-enrichment studies of woody and herbaceous vegetation.

CDIAC also continued its focus on the operation of the NARSTO Quality Systems Science Center (staffed by Les Hook, Tom Boden, Meng-Dawn Cheng, and Sig Christensen), to provide quality-assurance guidance for research on tropospheric ozone and particulates.

In the Ocean Data area, Alex Kozyr, assisted by Linda Allison, continued to quality-assure and document databases on ocean carbon (http://cdiac.esd.ornl.gov/oceans/home.html). As part of that effort, too, Forrest Hoffman maintained the web site for the Ocean Drifters project (http://drifters.doe.gov/); Forrest also maintains the web site for the multi-agency Global Change Data and Information System (http://www.gcdis.usgcrp.gov/) and the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (http://www.nacc.usgcrp.gov/).

This report also notes the several climate databases that Dale Kaiser, assisted by Linda Allison, produced during the year. A section on CDIAC's computing systems describes the many changes and enhancements to our systems (most of which were *not* inspired by the Y2K issue) implemented by Tommy Nelson and Jim Simmons. For many of our customers, the first line of contact with CDIAC is through our Information Services group (Sonja Jones,

Karen Gibson, and Marvel Burtis); this report summarizes CDIAC's user statistics.

On a sad note, right after the end of the fiscal year, CDIAC's talented secretary Dana Griffith (who also had a hand in preparing several databases for publication) left CDIAC for the private sector. We'll all miss Dana, and we wish her the best. And we welcome Dana's replacement Gloria Taylor (previously with the ORNL Distributed Active Archive Center) to CDIAC.

Although most of our customers aren't aware of this (unless they study our mailing address), about a year ago CDIAC moved from the "charming" confines of Building 1000 to more modern quarters in nearby Building 1509. The move, and all the logistics associated therewith, went smoothly thanks to the heroic efforts of Dana Griffith, working with our division's Linda Armstrong and Linda Jennings and the Instrumentation and Controls Division's Randy Smith and Ed Stanford. Not only people and the contents of offices had to be moved, as well as our inventory of printed documents, but also our computing network had to be moved in a manner that minimized disruption to our own work and our communications with the outside world.

I would like to acknowledge the guidance and support of Bobbi Parra, CDIAC's Program Manager in the DOE's Office of Biological and Environmental Research; Roger Dahlman, who has oversight of CDIAC's AmeriFlux and FACE work; Wanda Ferrell, who oversees CDIAC's NARSTO effort; Anna Palmisano, who manages CDIAC's Ocean Data project; and all the other DOE global change program managers (Pat Crowley, Jerry Elwood, John Houghton, Peter Lunn, Rick Petty, and Mike Riches).

Robert M. Cushman

Introduction

The Carbon Dioxide Information Analysis Center (CDIAC), which includes the World Data Center (WDC) for Atmospheric Trace Gases, is the primary global-change data and information analysis center of the Department of Energy (DOE). More than just an archive of data sets and publications, CDIAC has—since its inception in 1982—enhanced the value of its holdings through intensive quality assurance, documentation, and integration. Whereas many traditional data centers are discipline-based (for example, meteorology or oceanography), CDIAC's scope includes potentially anything and everything that would be of value to users concerned with the greenhouse effect and global climate change, including concentrations of carbon dioxide (CO_2) and other radiatively active gases in the atmosphere; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of CO_2 and other trace gases to the atmosphere; long-term climate trends; the effects of elevated CO_2 on vegetation; and the vulnerability of coastal areas to rising sea level.

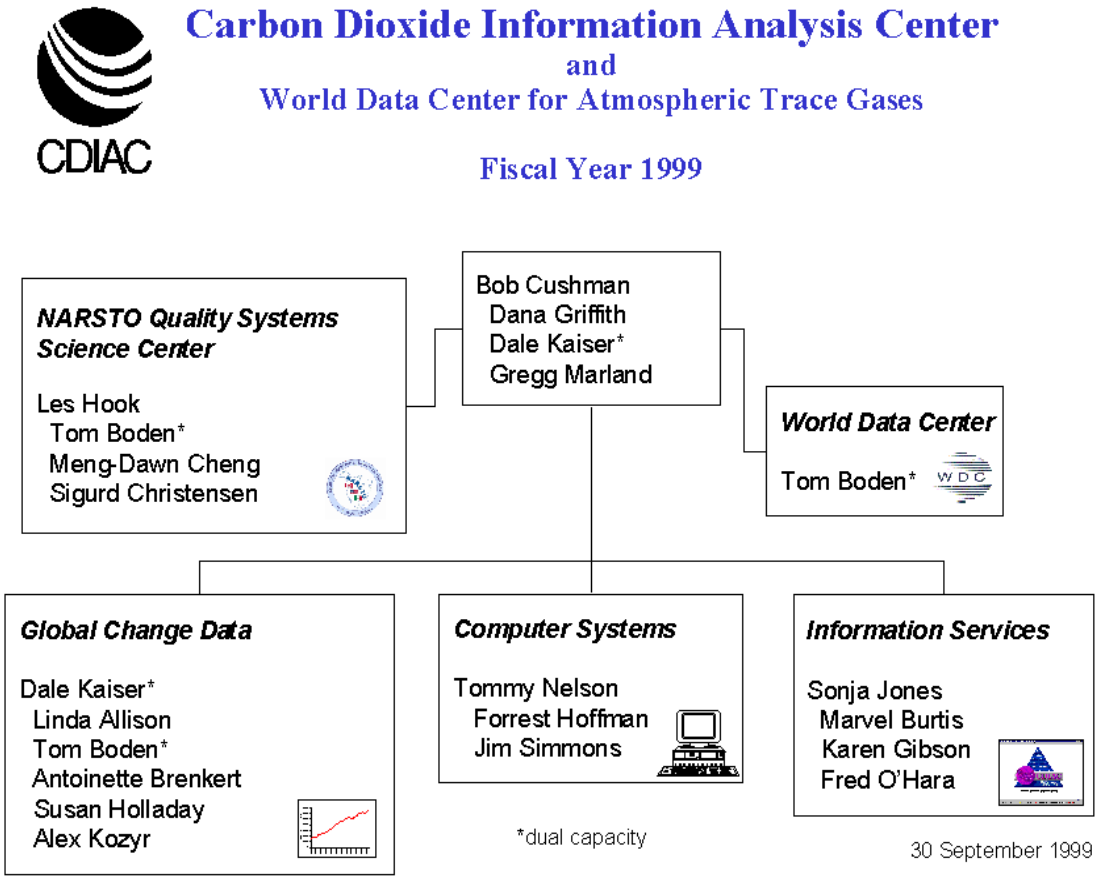
CDIAC is located within the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. CDIAC is co-located with ESD researchers investigating global-change topics, such as the global carbon cycle and the effects of carbon dioxide on vegetation. CDIAC staff are also connected with current ORNL research on related topics, such as renewable energy and supercomputing technologies.

CDIAC is supported by the Environmental Sciences Division (Jerry Elwood, Acting Director) of DOE's Office of Biological and Environmental Research. CDIAC's FY 1999 budget was 2.2M dollars. CDIAC represents the DOE in the multi-agency Global Change Data and Information System. Bobbi Parra, and Wanda Ferrell on an interim basis, is DOE's Program Manager with responsibility for CDIAC.

CDIAC comprises three groups, Global Change Data, Computer Systems, and Information Services, with seventeen full-time and part-time staff. The Global Change Data group is responsible for identifying and obtaining databases important to global-change research, analyzing data, compiling needed databases, providing data management support to specific programs (e.g., NARSTO), and preparing documentation to ensure the long-term utility of CDIAC's data holdings. The Computer Systems group provides computer system support for all CDIAC and WDC activities, including designing and maintaining CDIAC's computing system network; ensuring compliance with ORNL/DOE computing security regulations; ensuring long-term preservation of CDIAC data holdings through systematic backups; evaluating, developing, and implementing software; ensuring standards compliance; generating user statistics; providing Web design, development, and oversight; and providing systems analysis and programming assistance for scientific data projects.

The Information Services group responds to data and information requests; maintains records of all request activities; assists in Web development and maintenance; and produces CDIAC's newsletter, *CDIAC Communications*, catalog, glossary, and educational materials. The following section provides further details on CDIAC's organization.

Organization



Focus Areas

AmeriFlux

Since 1997, CDIAC has been funded by DOE to provide data management support for the AmeriFlux network. AmeriFlux investigators measure the net flux of CO_2, using the eddy-covariance method, to and from major terrestrial ecosystems. The aim of this long-term, continuous monitoring network is to better understand the factors regulating CO_2 exchange, including soil processes, vegetation structure, physiology, and stage of succession, and to determine principal feedbacks that affect the future, such as response to changes in climate, air pollution, and CO_2 concentrations.

The scientific objectives of AmeriFlux are to establish an infrastructure for guiding, collecting, synthesizing, and disseminating long-term measurements of CO_2, water, and energy exchange from a variety of ecosystems; collect critical new information to help define the current global CO_2 budget; enable improved predictions of future concentrations of atmospheric CO_2; and enhance understanding of carbon fluxes, Net Ecosystem Production (NEP), and carbon sequestration in the terrestrial biosphere.

The present AmeriFlux network now comprises approximately 40 sites in Brazil, Canada, Costa Rica, and the United States. These sites span a large variety of ecosystems, climate regimes, elevations, and stand ages. For more details on AmeriFlux and related data activities, please visit the AmeriFlux Web site at http://cdiac.esd.ornl.gov/programs/ameriflux/.

The primary responsibilities of the CDIAC AmeriFlux data archive are to archive AmeriFlux data forever; check contributed AmeriFlux data to ensure quality and consistency; assemble consistent documentation to ensure long-term use of AmeriFlux data; compile ancillary information for each AmeriFlux site [e.g., leaf area index (LAI), land-use histories] for the purpose of creating network-wide databases; and create and maintain an AmeriFlux Web site.

The AmeriFlux data archive at CDIAC offers two types of AmeriFlux data. Preliminary data are contributed by AmeriFlux principal investigators (PIs). The file formats and contents are unchanged from their original submission state. Any descriptive files provided are those furnished by the site PIs. The values provided in these preliminary files have been scrutinized by the PIs but are subject to change. Preliminary AmeriFlux data are kindly contributed to CDIAC and made available in order to make AmeriFlux measurement data available as quickly as possible.

Preliminary AmeriFlux data sent to CDIAC are checked, processed into a consistent data format, and documented by CDIAC before release as a final data set. All data issues investigated by CDIAC are resolved with the contributing PIs, and no values are changed without the approval of the contributing AmeriFlux PIs.

Noteworthy developments during FY 1999

- Tom Boden replaced Antoinnete Brenkert as the AmeriFlux data manager. Antoinette was the first AmeriFlux data manager and laid much of the existing foundation for the AmeriFlux data archive. Susan Holladay continues to assist with AmeriFlux data activities and Web development.

- Tom Boden attended the AmeriFlux Science Team Meeting at Harvard Forest (October 1998).

- The CDIAC AmeriFlux archive was designated as the hub for an FY 2000 validation exercise. Micrometeorological

flux measurements from AmeriFlux sites will be used, along with Gross Primary Production (GPP) estimates obtained from the moderate-resolution imaging spectroradiometer (MODIS) sensor launched December 1999 on the National Aeronautics and Space Administration (NASA) Terra satellite, in the global biome model-biogeochemical cycle (BIOME-BGC) model, and other models, to calculate GPP, NEP, and Net Primary Production (NPP). The model-calculated GPP, NEP, and NPP estimates will then be compared with the same estimates derived from measurements at the individual AmeriFlux sites.

Databases

- The first final database to be posted came from the oldest of the AmeriFlux sites, Harvard Forest, and was contributed by Bill Munger and Steve Wofsy, Harvard University; Dave Fitzjarrald and Kathy Moore, State University of New York (SUNY)-Albany; Mike Goulden, University of California (UC)-Irvine; and Allen Goldstein, UC-Berkeley. The flux, hydrocarbon, and trace-gas profiles provided from the Harvard Forest mixed, deciduous forest site cover the period 1990–1996.

- The second final database to be posted on the AmeriFlux area offers flux measurements for 1995–1996 from an old-growth ponderosa pine site in Metolius Natural Research Area, Oregon. The data were contributed by Bev Law, Peter Anthoni, and Michael Unsworth, Oregon State University.

- Preliminary data were posted for the following sites and periods.

  Happy Valley, Alaska (moist, acidic tundra) 1994–1995

  U-Pad, Alaska (moist, wet sedge tundra) 1994–1995

  Bondville, Illinois (agricultural crops, alternating corn and soybeans) 1996–1998

  Howland Forest, Maine (boreal, northern hardwood forest) 1996–1997

  Little Washita Watershed, Oklahoma (rangeland) 1996–1998

  Ponca City, Oklahoma (agricultural crops, wheat) 1996–1997

  Shidler, Oklahoma (tallgrass prairie) 1996–1997

  Walker Branch Watershed, Oak Ridge, Tennessee (deciduous forest) 1995–1998

  BOREAS Northern Study Area, Thompson, Manitoba (old black spruce forest) 1994–1998

Web Developments

- provided all presentations from the October 1998 AmeriFlux Science Team Meeting at Harvard Forest,

- added a new section entitled “Equipment Sources, Tips, and Techniques” to help new and existing AmeriFluxers,

- added a new section entitled “Model Validation” describing the upcoming FY 2000 model validation effort,

- added a paper written by Eva Falge on gap-filling strategies, and

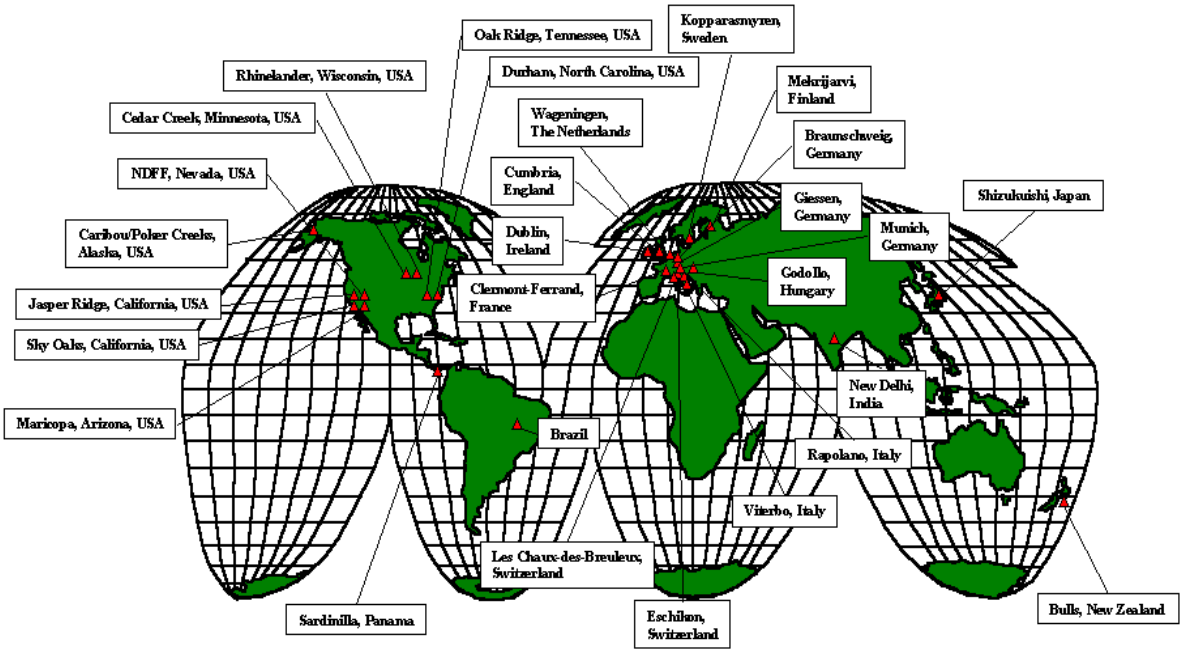
- updated the list of AmeriFlux measurement parameters, standard definitions, and preferred reporting formats and maintained the lists of AmeriFlux sites and participants.

Free-Air CO_2 Enrichment (FACE)

Studies of the effects of CO_2 enrichment on vegetation and ecosystems have always been constrained by the experimental equipment (e.g., open-top chambers), which limited the size and temporal duration of the studies. But in the past few years, the FACE design, pioneered at Brookhaven National Laboratory and now in use or in development at approximately thirty sites around the world, overcomes some of those obstacles and permits more ecologically realistic studies. In FY 1999, CDIAC began a web site for FACE (http://cdiac.esd.ornl.gov/programs/FACE/face.html).

This site provides a network for the many FACE experiments under way or planned. CDIAC's FACE site provides background information about the FACE research approach and shows the sites and summary information about each experiment, with links to contacts for each study. It also provides a listing of FACE-related publications. The initial design and construction of the site was handled by CDIAC summer student Stephen Henderson from Allegheny College; following Stephen's return to school in the fall, Bob Cushman and Sonja Jones continued to develop the site. We hope to move more actively into the management of data from FACE research.

FACE Sites Around the World



NARSTO Quality Systems Science Center (QSSC)

NARSTO is a nonbinding, tri-national public/private alliance, open to science agencies, regulatory agencies, regulated industries, academic institutions, environmentalists, and public interests groups in Canada, Mexico, and the United States. Its primary mission is to coordinate and enhance policy-relevant scientific research, assessment, and modeling of tropospheric pollution behavior, with the central programmatic goal of determining workable, efficient, and effective strategies for local and regional air-pollution management.

In January 1997, DOE's Environmental Sciences Division began their sponsorship of the NARSTO Quality Systems Science Center (QSSC) within CDIAC. The QSSC reports to the NARSTO Executive Steering Committee through the NARSTO Management Coordinator and collaborates with the Science Teams.

The QSSC works to ensure that relevant quality management systems are planned and implemented by NARSTO technical programs. The ***NARSTO Quality Systems Management Plan (QSMP)*** and the ***Quality Planning Handbook (QPHB)***, developed and maintained by the QSSC, form the umbrella under which all quality-related activities are conducted.

The QSSC reviews project management and fieldwork planning documents and provides information to NARSTO partners seeking assistance with quality assurance, quality control, data management, and data archival. The QSSC plans and coordinates NARSTO data management, data archival, and data dissemination activities. Timely sharing of and access to quality assured NARSTO data and research products (e.g., computer models, methods, procedures, and reports) by the scientific community is essential to the success of the NARSTO program. The QSSC developed and maintains the ***NARSTO Data Management Handbook (DMHB)*** that contains data format conventions, data validation guidance, and data archive transfer format specifications. The QSSC performs a final quality assurance check of data sets submitted for archival, prepares archive documentation, and coordinates their transfer to the publicly available NARSTO Permanent Data Archive at the NASA Langley Distributed Active Archive Center (DAAC). Data are online at http://eosweb.larc.nasa.gov/.

NARSTO quality systems and data management documents are available online at http://cdiac.esd.ornl.gov/programs/NARSTO/.

In addition to these quality and data management activities, the QSSC designed and continues to develop the ***NARSTO Measurement Methods Compendium*** Web site for ozone and particulate matter sampling and analysis technologies and methodologies. Method descriptions are available online at http://narsto.esd.ornl.gov/Compendium/.

QSSC staff expertise includes atmospheric chemistry, quality systems management, environmental data quality management, and data management coordination.

The FY 1999 QSSC's activities fall into three general areas: quality management support, data quality assurance and archiving, and external interactions.

Quality Management Support

The QSSC updated two of the quality management documents, the QSMP and the DMHB, to reflect NARSTO's changing scope and several refinements in data archive format guidance.

The QSSC initiated the *NARSTO Measurement Methods Compendium* Web site for ozone and particulate matter sampling and analysis technologies and methodologies. Added first were method descriptions for Federal Reference Methods (FRM) and Federal Equivalent Methods (FEM) for ozone, nitrogen dioxide (NO_2), and carbon monoxide (CO). The FRM/FEM sampling method descriptions were added for particulate matter (PM10 and PM2.5). For organics, two tables of sampling and analysis summary information for Photochemical Assessment Monitoring Stations (PAMS) volatile organic compound (VOC) target species and non-methane organic compound (NMOC) method descriptions were added.

Interactions with NARSTO technical partners included assisting the California Air Resources Board with reviews of work wlans, requests for proposals (RFPs), proposals, and data management system design. We also provided quality management documentation to several academic institutions.

Data Quality Assurance and Archiving

The QSSC evaluated data sets submitted for archival, prepared archive documentation, and coordinated their transfer to the NARSTO Permanent Data Archive at the NASA Langley DAAC. The NARSTO 1998 Model-Intercomparison Study Verification Data: NARSTO-Northeast 1995 Surface Ozone, NO, and NO_x and the NARSTO-NE 1995 NEXRAD image data were submitted.

The QSSC also provided NARSTO-Northeast and NARSTO-Canada East with data quality assurance feedback and continue to work with them to resolve data quality issues.

External Interactions

QSSC promotes coordination of NARSTO Data Exchange standards and automated processing programs with Bill Sukloff of the Atmospheric Environment Service (AES) of Canada. We leverage existing resources (people and software) to the benefit of both programs. The QSSC cosponsored a 10-day visit by Bill Sukloff for this purpose.

The QSSC sponsored the 12-month appointment of a student from the Oak Ridge Institute for Science and Education (ORISE) Technical Intern Program. Robert Lowery, gathered methods information for the Methods Compendium. The QSSC also sponsored a DOE Energy Research Undergraduate Laboratory Fellowship (ERULF) summer student, Craig Harvey, to evaluate ozone forming potential at several northeastern U.S. sites.

QSSC Staff gave presentations on the Data Exchange Standard at the World Meteorological Organization (WMO) meeting last year in Norway and for a recent visitor from Japan.

QSSC staff participated in NARSTO-sponsored meetings and workshops including the NARSTO Fine Particle Workshop, January 26–29, 1999, and the “Expert Workshop on Monitoring and Assessment in Support of the Sound Management of Chemicals Initiative” sponsored by the North American Free Trade Agreement (NAFTA) Commission on Environmental Cooperation, May 3–4, 1999.

Ocean Data

The World Ocean Circulation Experiment (WOCE) Hydrographic Program (WHP) is a major component of the World Climate Research Program with the overall goal to better understand the ocean's role in climate and climatic changes resulting from both natural and anthropogenic causes. The levels of CO_2 in the oceans are unevenly distributed because of complex circulation patterns and biogeochemical cycles. Although total CO_2 (TCO_2) is not an official WOCE measurement, a coordinated effort, supported in the United States by DOE, was made on WOCE cruises through 1998 to measure the global spatial and temporal distributions of TCO_2 and other related parameters. Goals of the survey were to estimate the meridional transport of inorganic carbon in a manner analogous to the estimation of the transport of oceanic heat, and to build a database suitable for carbon cycle modeling and the estimation of anthropogenic CO_2 increase in the oceans. The CO_2 survey took advantage of the sampling opportunities provided by the WHP cruises during this period. The final data set is expected to cover ~23,000 stations from 42 WOCE cruises.

CDIAC provides data management support for the Joint Global Ocean Flux Study (JGOFS) CO_2 measurements taken aboard research vessels during WHP cruises. The DOE sponsored CO_2 measurement operations and continues to sponsor CDIAC's data support activities, which include data archival, data checking and evaluation, preparation of data documentation, and data dissemination. All CO_2-related data are checked before documentation and distribution. Through the end of FY 1999, DOE-supported investigators had collected CO_2 measurements on 42 WOCE cruises. CDIAC has received data from 38 of these cruises, and 25 of these data sets have undergone quality assurance checks with 10 fully documented as NDPs.

One of the noteworthy developments is the willingness of scientists supported by the National Oceanic and Atmospheric Administration's (NOAA) Ocean-Atmosphere Carbon Exchange Study (OACES) to archive their CO_2-related measurements at CDIAC for comparison, documentation and distribution purposes. Two documents that provide data obtained during NOAA/Pacific Marine Environment Laboratory (PMEL) cruises in the Pacific and Indian oceans have been recently completed at CDIAC.

As new measurements are made and submitted to CDIAC, it will be possible to compare measurements obtained at identical locations during different expeditions to assess their agreement. This is particularly important for measurements made in deep and abyssal waters. These checks will assess the geographical consistency of the CO_2-related parameters (TCO_2, pCO_2, alkalinity, and pH), salinity, and the concentrations of dissolved oxygen and macro-nutrients along constant seawater density surfaces.

The National Oceanographic Partnership Program (NOPP) of DOE and eleven other federal agencies developed Project NOPP Drifters to engage the education community in study of the oceans by making available real-time data from dozens of "drifters"—instrumented devices that float on the ocean surface and drift with the ocean currents, transmitting data on location, salinity, sea-surface temperature, and other variables via satellite. On behalf of DOE, CDIAC's Forrest Hoffman developed the Project NOPP Drifters Web page (http://drifters.doe.gov/), with important linked information furnished by other NOPP partners. From the Project NOPP Drifters Web page, users can track individual drifters (and predict movement of icebergs and pollutants), study global warming, monitor El Niño and La Niña, follow hurricanes, verify satellite data, build their own drifters, see images of the oceans, ask questions of professional oceanographers, and follow links to related Web sites.

Data and Information Products

New Products

CDIAC's data and information holdings provide coverage in a number of areas relevant to the greenhouse effect and global climate change. Data available from CDIAC that have been thoroughly checked and documented are released by CDIAC as numeric data packages (NDPs) or computer model packages (CMPs). CDIAC also offers database products that do not include the extensive documentation of the NDPs in order to make the data available more quickly. The data and documentation text may be accessed and downloaded from CDIAC's Web site (http://cdiac.esd.ornl.gov/), from CDIAC's anonymous FTP area (cdiac.esd.ornl.gov), or requested directly from CDIAC on a variety of media (e.g., CD ROM, 8 mm tape, floppy diskette). Printed reports and information may also be requested from CDIAC. Technical questions (e.g., methodology or accuracy) should be directed to the CDIAC staff member responsible for preparing the data.

- **Atmospheric Trace Gases**

  Measurement of Air Pollution from Satellites (MAPS) 1994 Correlative Atmospheric Carbon Monoxide Mixing Ratios (DB1020) by Paul Novelli, National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory (CMDL), and Ken Masarie, University of Colorado, Cooperative Institute for Research in Environmental Sciences (CIRES). These data were prepared for online distribution by CDIAC's Linda Allison and Tom Boden. The MAPS correlative data set (CO mixing ratios from eleven fields and aircraft measurement programs around the world) was compiled to permit a validation of measurements taken from the space shuttle *Endeavour*. The data show the regional importance of fossil-fuel burning and biomass burning as CO sources. (http://cdiac.esd.ornl.gov/epubs/db/db1020/db1020.html)

  Measurements of Atmospheric Methane and $^{13}C/^{12}C$ of Atmospheric Methane from Flask Air Samples by Paul Quay and Johnny Stutsman, University of Washington, and prepared for online distribution by CDIAC's Tom Boden. This database offers precise measurements of atmospheric methane, and its $^{13}C/^{12}C$ isotopic ratio, from flask air samples collected at eight sites worldwide and aboard NOAA cruises in the Pacific Ocean. The eight sites include Olympic Peninsula, Washington; Cape Grim, Tasmania; Fraserdale, Ontario; Marshall Islands; Baring Head, New Zealand; Mauna Loa, Hawaii; Point Barrow, Alaska; and American Samoa. The measurements span the period 1988 to mid-1996. These data are useful for global methane budget analyses and for determining the atmospheric isotopic composition of methane. All isotopic measurements have been corrected for standard drift. (http://cdiac.esd.ornl.gov/ndps/quay.html)

- **Climate**

  Extended Edited Synoptic Cloud Reports from Ships and Land Stations Over the Globe, 1952–1996 (ORNL/CDIAC-123, NDP-026C) by Carol Hahn, University of Arizona, and Stephen Warren, University of Washington, and prepared by CDIAC's Dale Kaiser. This NDP contains surface synoptic weather reports for the entire globe, gathered from various available data sets. In addition to the cloud portion of the synoptic report, each edited report also includes the associated pressure, present weather, wind, air temperature, and dew point (and sea surface temperature over oceans). This database contains 71 million cloud observations from ships and 311 million observations from land stations. This data set will be useful for such applications as: (1) development of user-defined cloud climatologies for particular subtypes of

clouds or for different temporal and spatial resolutions than Hahn and Warren have chosen in their published cloud atlases; (2) in comparison of satellite cloud retrievals with surface observations to help diagnose difficulties in cloud identification from satellite; and (3) to relate formation of individual types of clouds to their meteorological environments. (http://cdiac.esd.ornl.gov/epubs/ndp/ndp026c/ndp026c.html)

United States Historical Climatology Network Daily Temperature, Precipitation, and Snow Data for 1871–1997 (ORNL/CDIAC-118, NDP-070) by David Easterling, Thomas Karl, Jay Lawrimore, and Stephen Del Greco, National Climatic Data Center (NCDC) and prepared by CDIAC's Dale Kaiser and Linda Allison. This NDP contains daily observations of maximum and minimum temperature, precipitation amount, snowfall amount, and snow depth from 1062 observing stations across the contiguous United States. Data from 1050 of the NDP-070 daily records extend into the 1990s, while 990 of these extend through 1997. This NDP is an expansion and update of the original 138-station database (funded in part by DOE) previously released by CDIAC as NDP-042 in 1992. Studies using daily data may be able to detect changes in regional climate that would not be apparent from analysis of monthly temperature and precipitation data, such as analyses of trends in maximum and minimum temperatures, temperature extremes, daily temperature range, precipitation "event size" frequency, and the magnitude and duration of wet and dry periods. The data are also valuable in such areas as climate model validation and climate change impact assessment. (http://cdiac.esd.ornl.gov/epubs/ndp/ndp070/ndp070.html)

- **Carbon Cycle—Oceans**

  Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V Meteor *Cruise 22/5 in the South Atlantic Ocean (WOCE Section A10, December 1992–January 1993* (ORNL/CDIAC-113, NDP-066) by Kenneth Johnson and Douglas Wallace, Brookhaven National Laboratory (BNL); Bernd Schneider, Baltic Sea Research Institute [Institut für Ostseeforschung (IOW), Rostock-Warnemünde, Germany]; and Ludger Mintrop, Institute for Marine Sciences (IfMK, Kiel, Germany) and prepared by CDIAC's Alex Kozyr. This NDP includes data on total and partial pressure of carbon dioxide; total alkalinity; CFC-11 and CFC-12; and nutrient, chemical, and physical variables measured during the 1992–1993 South Atlantic Ocean cruise of the R/V *Meteor* (between Rio de Janeiro, Brazil, and Capetown, South Africa). This database contributes to our understanding of the role of the oceans in the global carbon cycle. (http://cdiac.esd.ornl.gov/cdiac/oceans/ndp_066/ndp066.html)

  The International Intercomparison Exercise of Underway fCO_2 Systems During the R/V Meteor *Cruise 36/1 in the North Atlantic Ocean* (ORNL/CDIAC-114, NDP-067) by Arne Koertzinger, Ludger Mintrop, and Jan C. Duinker, Institute for Marine Sciences (IfMK,) Kiel, Germany and prepared by CDIAC's Alex Kozyr. This NDP contains measurements of carbon dioxide in surface seawater that are an important part of studies of the global carbon cycle and its anthropogenic perturbation. A thorough interpretation of the vast amount of available ocean fCO_2 ("*f*" refers to fugacity, a measure of concentration) data requires a knowledge of the comparability of data sets from different laboratories. To provide this information, an international

intercomparison involving nine groups from six countries (Australia, Denmark, Germany, France, Japan, and the United States) was carried out during the R/V *Meteor* Cruise 36/1 from Hamilton, Bermuda, to Las Palmas, Gran Canaria, Spain. The results of three of the seven underway systems agreed to within ±2 μatm throughout the cruise, and one system was in good agreement most of the time, but significant offsets of up to 10 μatm occurred in three systems. These results underline the need to address carefully the important issue of the inter-laboratory comparability of fCO_2 data. (http://cdiac.esd.ornl.gov/cdiac/oceans/ndp_067/ndp067.html)

Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V Thomas G. Thompson *Cruise in the Pacific Ocean (WOCE Section P10, October 5–November 10, 1993*) (ORNL/CDIAC-122, NDP-071) by Christopher Sabine and Robert Key, Princeton University, and Melinda Hall, Woods Hole Oceanographic Institution, and prepared by CDIAC's Alex Kozyr. This NDP discusses the procedures and methods used to measure total carbon dioxide (TCO_2), total alkalinity (TALK), and radiocarbon ($\Delta^{14}C$) at hydrographic stations, as well as the underway partial pressure of CO_2 (pCO_2). Conducted as part of the World Ocean Circulation Experiment (WOCE), the cruise began in Suva, Fiji, and ended in Yokohama, Japan. Data from this cruise are important for understanding the dynamics of the far western equatorial Pacific. The results can be used to infer the relative magnitude of various tracers to the North Pacific from the South China Sea and the Sea of Japan. WOCE Section P10 also provides a transect across the Kuroshio Current that can be used to better understand the northward transport of heat, salt, and other important ocean tracers. The underway surface measurements show a small outgassing of CO_2 at the equator. (http://cdiac.esd.ornl.gov/cdiac/oceans/ndp_071/ndp071.html)

- **Vegetation Response to CO_2 and Climate**

  A Database of Woody Vegetation Responses to Elevated Atmospheric CO_2 (ORNL/CDIAC-120, NDP-072) by Peter Curtis, Ohio State University, and prepared by CDIAC's Bob Cushman and Antoinette Brenkert. The NDP updates DB1018 (previously available from CDIAC). A multiparameter database of responses by woody vegetation to increased atmospheric CO_2 levels was compiled to support a statistically rigorous meta-analysis of research results across many studies. Data were retrieved from the published literature and unpublished reports for 84 independent CO_2 enrichment studies, covering 65 species and 35 response parameters. (http://cdiac.esd.ornl.gov/epubs/ndp/ndp072/ndp072.html)

Updated Products

- **Atmospheric Trace Gases**

  The ALE/GAGE/AGAGE Network (DB1001) by Ronald Prinn, Massachusetts Institute of Technology (MIT); Derek Cunnold, Fred Alyea, Ray Wang, and Dana Hartley, Georgia Institute of Technology; Paul Fraser and L. Paul Steele, Commonwealth Scientific and Industrial Research Organisation (CSIRO); Ray Weiss, Scripps Institution of Oceanography (SIO); and Peter Simmonds, International Science Consultants; and prepared for online distribution by CDIAC's Tom Boden. This network provides continuous high-frequency measurements of methane, nitrous oxide, three chlorofluorocarbons, methyl chloroform, chloroform, and carbon tetrachloride. This database supports analyses and monitoring related to both greenhouse gases and the Earth's ozone layer. Data from 1978 through September 1998 are now available for Cape Grim, Tasmania; Point Matatula, American Samoa; Ragged Point, Barbados; Mace Head, Ireland; and Trinidad Head, California

(stations also previously existed at Cape Meares, Oregon; and Adrigole, Ireland). All ALE and GAGE data have been recalculated according to the current AGAGE calibration standards, thus creating a unified ALE/GAGE/AGAGE data set based upon the same standards; and the AGAGE database has been completely re-computed to introduce a new and improved pollution analysis scheme. (http://cdiac.esd.ornl.gov/ndps/alegage.html)

- **Carbon Cycle—Emissions**

Global, Regional, and National CO_2 Emission Estimates from Fossil-Fuel Burning, Cement Production, and Gas Flaring: 1751–1996 (revised March 1999)(NDP-030) by CDIAC's Gregg Marland, Tom Boden, and Antoinette Brenkert; Bob Andres, University of Alaska–Fairbanks; and Cathy Johnston, the University of Tennessee–Knoxville. These data quantify CO_2 emissions from fossil-fuel combustion and cement production through 1996, with global total emissions and some national estimates beginning in 1751. The global total emissions rose from 3 million metric tons C in 1751 to 6518 million metric tons C in 1996; the United States accounted for 22% of the 1996 global total. (http://cdiac.esd.ornl.gov/ndps/ndp030.html)

Trends Online

- **Atmospheric Carbon Dioxide**

Atmospheric CO_2 Records from Sites in the SIO Air Sampling Network
Ambient atmospheric CO_2 data through 1998 from Mauna Loa, Hawaii (as well as Barrow, Alaska; Cape Matatula, Samoa; and the South Pole) were contributed by Dave Keeling and Tim Whorf, Scripps Institution of Oceanography (SIO), and prepared by CDIAC's Tom Boden and Dana Griffith. The Mauna Loa atmospheric CO_2 measurements constitute the longest continuous record of atmospheric CO_2 concentrations available in the world. The Mauna Loa site is considered one of the most favorable locations for measuring undisturbed air because possible local influences of vegetation or human activities on atmospheric CO_2 concentrations are minimal and any influences from volcanic vents can be excluded from the records. The methods and equipment used to obtain these measurements have remained essentially unchanged during the 40-year monitoring program. The Mauna Loa record shows a 16.1% increase in the mean annual concentration, from 315.83 parts per million by volume (ppmv) of dry air in 1959 to 366.70 ppmv in 1998. The 1997–1998 increase in the annual growth rate of 2.9 ppmv represents the largest single yearly jump since the Mauna Loa record began in 1958. (http://cdiac.esd.ornl.gov/trends/co2/sio-keel.htm)

Historical Carbon Dioxide Record from the Vostok Ice Core
Records of CO_2 derived from the Vostok (East Antarctica) ice core now include data extending back to 414,085 years before present. The data were contributed by J. M. Barnola, D. Raynaud, and C. Lorius, Laboratoire de Glaciologie et de Géophysique de l'Environnement, Saint Martin d'Heres Cedex, France, and N. I. Barkov, Arctic and Antarctic Research Institute, St. Petersburg, Russia, and prepared by CDIAC's Tom Boden and Dana Griffith. Ice cores are unique with their entrapped air inclusions enabling direct records of past changes in atmospheric trace-gas composition. The extension of the Vostok CO_2 record shows that the present-day levels of CO_2 are unprecedented during the past 420 kyr. (http://cdiac.esd.ornl.gov/trends/co2/vostok.htm)

- **Carbon Dioxide Emissions**

  Global, Regional, and National Fossil-Fuel CO_2 Emissions
  These records of global, regional, and national CO_2 emission estimates from fossil-fuel combustion and cement production were updated through 1996. The estimates were developed by Gregg Marland, Tom Boden, Bob Andres, Antoinette Brenkert, and Cathy Johnston and were prepared for *Trends Online* by Boden and Dana Griffith. The *Trends Online* format provides a concise summary of the methodology, time-series graphics, and tabular data in an easily downloadable format. Special listings are also provided for the top 20 emitting countries and for countries ranked by total and per capita emissions.
  (http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm)

  Kyoto-Related Fossil-Fuel CO_2 Emission Totals (table)
  Tom Boden and Gregg Marland have prepared a table that shows emissions of CO_2 from fossil-fuel combustion and cement production in a format that is relevant for analyses relating to the Kyoto Protocol. The table lists emissions for those countries listed in Annex B of the Kyoto Protocol and for those countries not listed in Annex B (as well as providing lists of the countries in each category).
  (http://cdiac.esd.ornl.gov/trends/emis/annex.htm)

- **Temperature**

  Global and Hemispheric Temperature Anomalies—Land and Marine Instrumental Records
  These records were updated through 1998 and were contributed by P. D. Jones, T. J. Osborn, and K. R. Briffa, University of East Anglia (Norwich, United Kingdom) and D. E. Parker, Hadley Centre for Climate Prediction and Research (Bracknell, UK) and prepared for online publication by CDIAC's Dale Kaiser. These data were corrected for nonclimatic errors, such as station shifts and/or instrument changes. The resulting data set has been used extensively in various Intergovernmental Panel on Climate Change (IPCC) reports, and the global-mean temperature changes evident in the record have been interpreted in terms of anthropogenic forcing influences and natural variability. Trends in annual mean temperature anomalies for the globe show relatively stable temperatures from the beginning of the record through about 1910, with relatively rapid and steady warming through the early 1940s, followed by another period of relatively stable temperatures through the mid-1970s, then another rapid rise similar to that earlier in the century. The year 1998, like 1997, has seen a new global mean temperature record set, and the six warmest years of the global record have all occurred since 1990.
  (http://cdiac.esd.ornl.gov/trends/temp/jonescru/jones.html)

- **Clouds**

  Trends in Total Cloud Amount Over China
  The first data set in this new section is contributed by CDIAC's Dale Kaiser. The cloud data were extracted from a database of 6-hourly weather observations, covering 196 stations from 1951 through 1994, provided by the National Climate Center of the China Meteorological Administration to CDIAC through a bilateral research agreement. Station and regional trends in annual and seasonal mean cloud amount clearly indicate decreasing total cloud amount over much of China during this period. Increases in cloud amount have been offered as a possible explanation for increased minimum temperatures in other parts of the world. In China, it seems that some different mechanism(s) must be considered for understanding the observed increase in minimum temperatures, perhaps relating to atmospheric circulation or urbanization

effects not fully removed from the temperature record. (http://cdiac.esd.ornl.gov/trends/clouds/kaiser/kaiser98.html)

Newsletters, Reports, and Additional Online Publications

- ***Catalog of Databases and Reports*** (ORNL/CDIAC-34), compiled by Marvel Burtis. The catalog provides information about the many reports and materials made available by CDIAC. The catalog indicates the databases and reports that are available in enhanced format (e.g., with hyperlinks and graphics) from CDIAC's Web site. (http://cdiac.esd.ornl.gov/epubs/catalog/index.htm) (http://cdiac.esd.ornl.gov/epubs/catalog/catalgpdf.pdf)

- ***CDIAC Communications*** edited by Sonja Jones and Karen Gibson

  Issue Number 25, Fall 1998. This issue featured stories on standards for measurement of ocean carbon and Year-of-the-Ocean drifters. (http://cdiac.esd.ornl.gov/newsletr/fall98/ccf98.htm) (http://cdiac.esd.ornl.gov/newsletr/fall98/ccf98.pdf)

  Issue Number 26, Summer 1999. This issue featured stories on the Throughfall Displacement Experiment (a large experimental test of climate-change impacts on a forest ecosystem), recent developments at the NARSTO Quality Systems Science Center, and Mercury (a new data management tool being developed at ORNL). (http://cdiac.esd.ornl.gov/newsletr/summer99/ccs99.htm) (http://cdiac.esd.ornl.gov/newsletr/summer99/ccs99.pdf)

- ***Fiscal Year 1998 Annual Report*** (ORNL/CDIAC-116), by CDIAC's Bob Cushman, Tom Boden, Sonja Jones, Dale Kaiser, and Tommy Nelson and compiled by Marvel Burtis and prepared for online distribution by Karen Gibson. The report documents highlights from the 1998 fiscal year including new data products and other publications; provides statistics, such as the number of requests for global-change data and information from CDIAC and of citations in the published literature of data obtained from CDIAC; alerts users to new data products that CDIAC hoped to release in FY 1999; lists awards received by CDIAC and publications and presentations of its staff; and lists the many organizations with which CDIAC has collaborated to produce the data and information products it released in FY 1998. (http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac116/98annual.htm) (http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac116/98annual.pdf)

- ***Selected Translated Abstracts of Chinese-Language Climate Change Publications*** (ORNL/CDIAC-117) by Ge Quansheng, Zhang Peiyuan, Liu Xiuping, Zhang Xueqing, Chen Yuan, Peng Guitang, and Zheng Jingyun, Institute of Geography (IG) of the Chinese Academy of Sciences and Wei-Chyung Wang of the Atmospheric Sciences Research Center (ASRC) of the State University of New York–Albany and compiled by CDIAC's Bob Cushman and Marvel Burtis, with technical editing by Linda O'Hara. The bibliography includes citations and abstracts, in both Chinese and English, from Chinese-language literature published in 1995–1998 in the following topical areas: adaptation, ancient climate change, climate variation, the East Asia monsoon, historical climate change, impacts, modeling, and radiation and trace-gas emissions. (http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac117/cdiac117.html)

- ***The NARSTO Quality Systems Science Center*** released Revision 2 of the NARSTO Data Management Handbook (ORNL/CDIAC-112/R2). The revised Handbook, authored by Sig Christensen, Tom Boden, Les Hook, and Meng-Dawn Cheng, features changes, clarifications, and details in the description of the NARSTO Data Exchange Standard. A new example file/template is included for user reference. The changes made requirements more explicit, thus enabling more reliable automated quality assurance verification of file format and content. (http://cdiac.esd.ornl.gov/programs/NARSTO/narsto.html) (http://cdiac.esd.ornl.gov/programs/NARSTO/) PDF file

- **Current Greenhouse Gas Concentrations**, updated by CDIAC's Tom Boden, this online table offers current levels of carbon dioxide and eleven other greenhouse gases, including data on pre-industrial (1860) concentrations, present tropospheric concentrations, global warming potentials, and atmospheric lifetimes. All data are referenced to published sources. This information should prove a convenient reference for global change studies and for analyses related to the Kyoto and Montreal protocols. (http://cdiac.esd.ornl.gov/pns/current_ghg.html)

- ***A Coastal Hazards Data Base for the U.S. West Coast*** (ORNL/CDIAC-81, NDP-043C) CDIAC put online the version of this numeric data package originally published in November 1997. This NDP was contributed by Vivien Gornitz of the NASA Goddard Institute for Space Studies (GISS), edited by former CDIACers Tammy Beaty and Richard Daniels, and formatted for online distribution by Karen Gibson. It describes the contents of a digital database that may be used to identify coastlines along the U.S. West Coast that are at risk to sea-level rise (and complements earlier data packages covering the East Coast and Gulf Coast). The data package contains information on elevation, geology, geomorphology, sea-level trends, shoreline displacement (erosion/accretion), tidal ranges, and wave heights, as well as several algorithms for combining these data to calculate a Coastal Vulnerability Index. (http://cdiac.esd.ornl.gov/epubs/ndp/ndp043c/43c.htm)

Systems Development

We are continually searching for ways to increase our efficiency wherever possible. One area where our efforts proved successful was our move to make products available electronically via our Web area (http://cdiac.esd.ornl.gov/) and our anonymous FTP area (cdiac.esd.ornl.gov/). By moving to electronic distribution, we cut publication and distribution costs, while reaching an expanding audience. The response to Web-accessible electronic publications and data has been tremendous. This response by our user community is exactly what we hoped to achieve.

Infrastructure Upgrades

The growth in electronic distribution, projections for continued growth in this area, the trend to larger data sets, and the resulting need to interactively subset data has established a clear need for a larger server and software to keep pace with user requests and computing demands. In response to this need, in FY 1999, we purchased and implemented a new 4-processor Sun Enterprise 450 server, doubled our redundant array of independent disks (RAID) storage capacity, purchased and implemented an automated digital linear tape (DLT) storage library to facilitate backup of our new RAID capacity, and upgraded our data management and analysis software to include some exciting new products (e.g., SAS® IntrNet) to facilitate dynamic subsetting of data for electronic delivery. This new hardware/software configuration not only meets our present needs but also offers migration paths to accommodate future needs.

We also began upgrading our communications network. We completed hardware orders for the equipment necessary to move from fixed transmission rates to a fiber-based, switched system. This upgrade, to be completed in FY 2000, will result in a ten fold increase of our network throughput and much more efficient routing of network traffic. We are excited to be able to offer these enhancements to our user community and look forward to building upon our new foundation.

Y2K Preparations

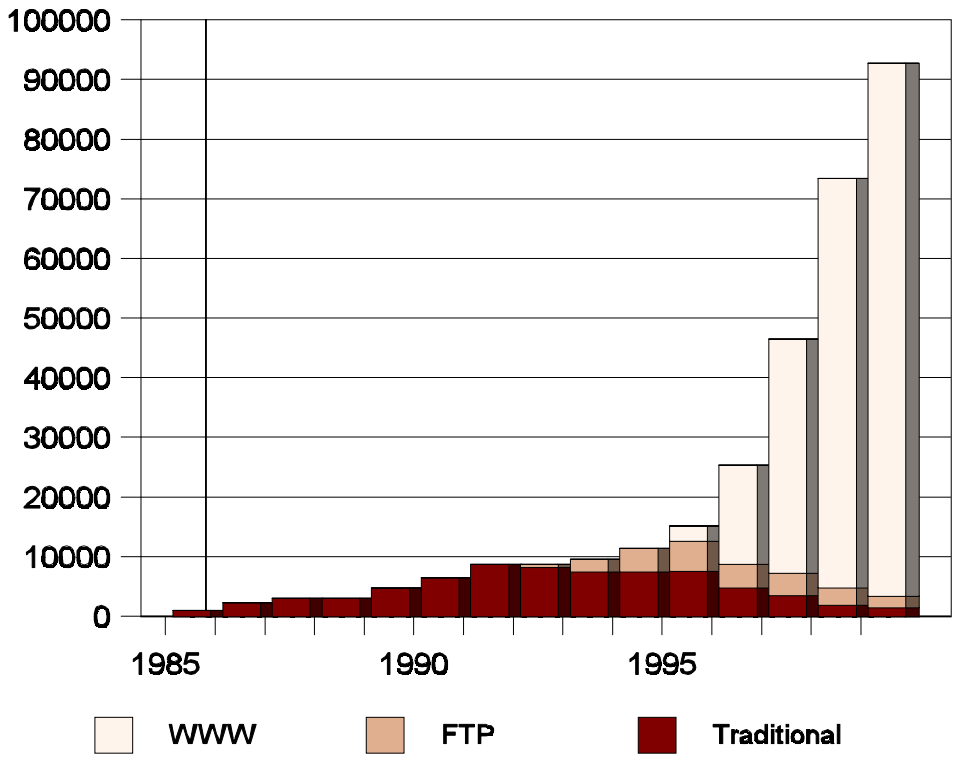
In addition to upgrading our computing infrastructure and performing routine computing activities, we had a busy year addressing Y2K concerns. We were constantly evaluating and reevaluating our software and hardware to ensure compliance with DOE and ORNL Y2K guidelines. As a result of Y2K guidelines, we installed a multitude of application and operating system upgrades and patches and are well prepared for the new millennium.

Information Services

FY 1999 Statistics

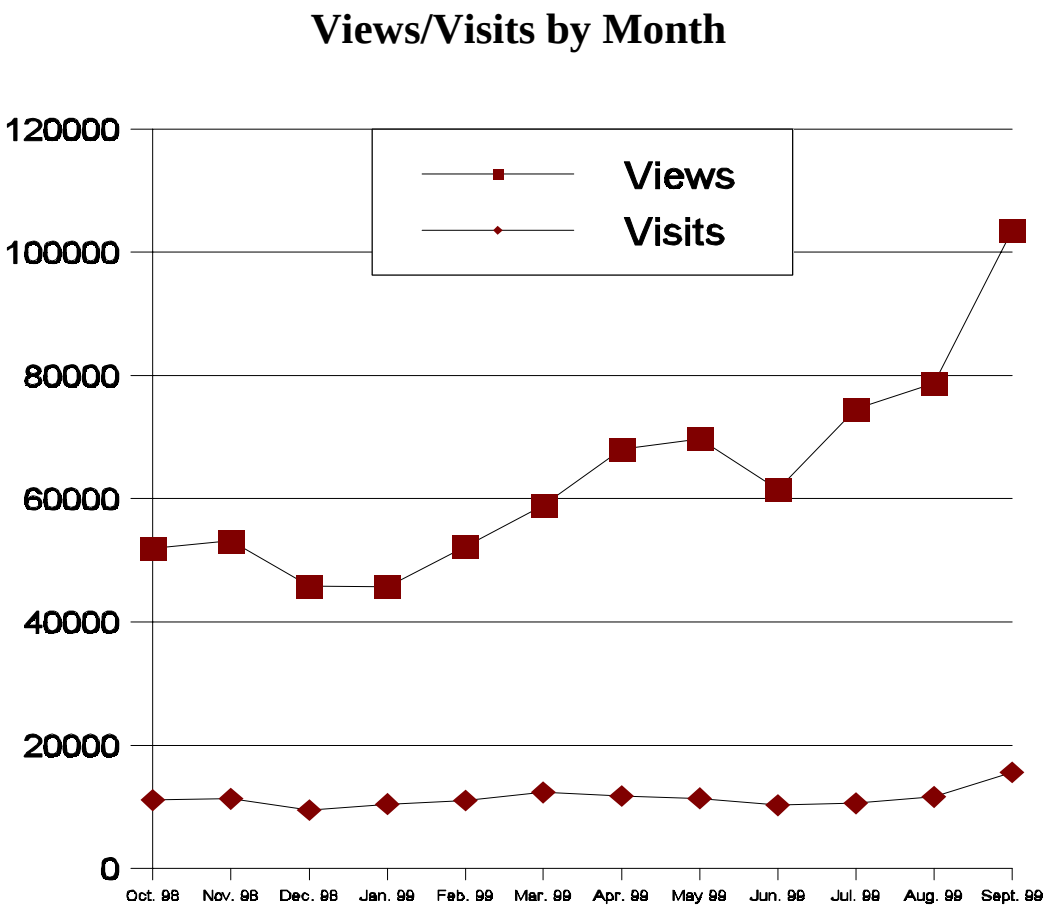
- In FY 1999, CDIAC received an all-time high of 92,000 requests for data and information products, representing a 26% increase in requests compared with FY 1998.
- Traditional requests (i.e., mail, fax, telephone) and direct accesses continued to decline in FY 1999, accounting for only 3,400 of the total number of requests.
- In FY 1999, CDIAC distributed data and information products on 135 custom-made CD-ROMs, 69 floppy diskettes, and 29 8mm tapes. In FY 1995, CDIAC distributed 248 of the two-volume CDIAC CD-ROMs, 832 floppy diskettes, 39 8mm tapes, 31 9-track magnetic tapes, and five 150-MB QIC tapes.

Requests to CDIAC Exceed 92,000

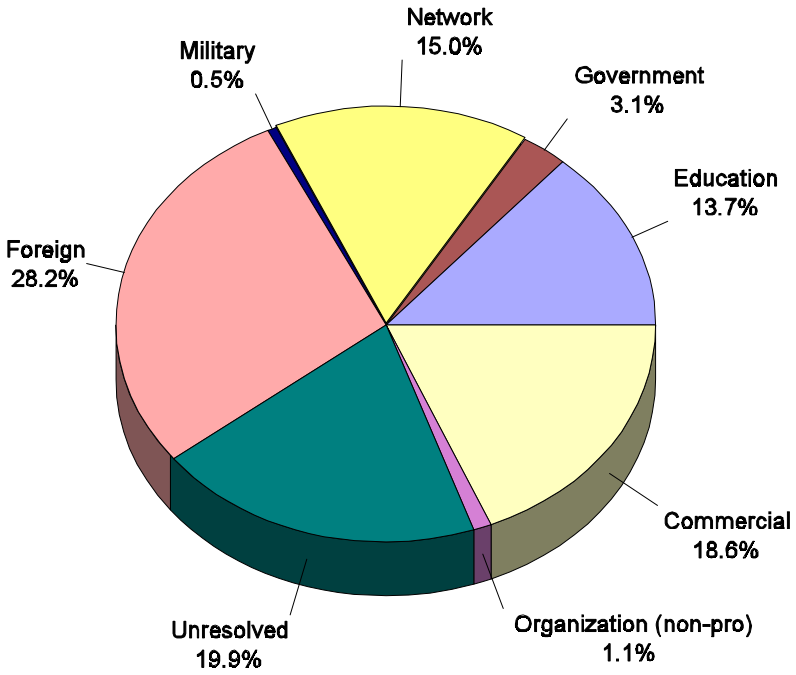


FY 1999 Web Statistics

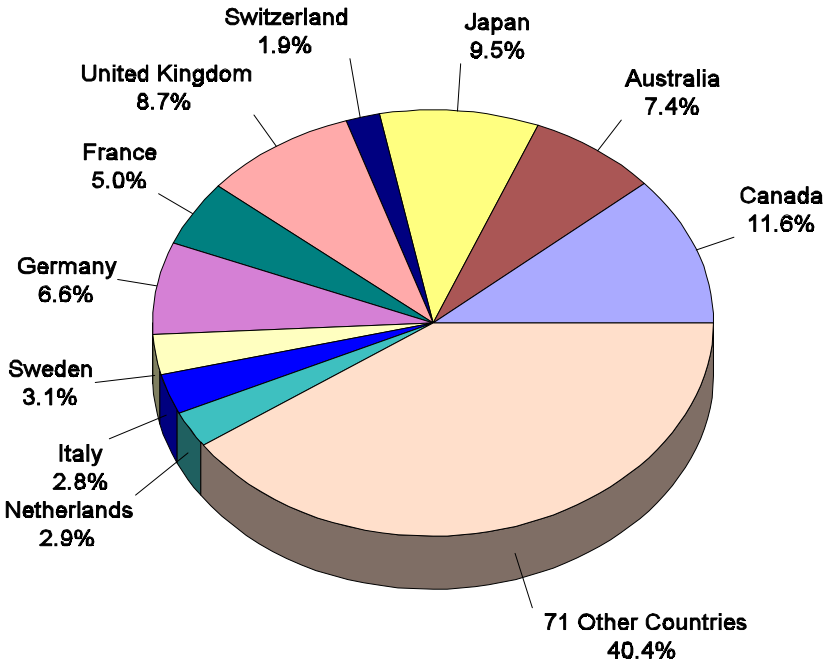
- CDIAC users made 137,000 visits to CDIAC's Web site, viewing more than 760,000 web pages (an average of 2,088 pages were viewed per day, and the site was visited an average of 376 times per day).
- Visits to CDIAC's Web site were made from 90 domains, including 81 foreign countries. In comparison, systems from 33 countries visited CDIAC's Web site in FY 1995.
- Top keywords used to locate CDIAC data and information products via online search engines (e.g., AltaVista, Yahoo, Excite, etc.) were "carbon dioxide, carbon, cdiac, carbon dioxide emissions, ameriflux, CO_2, and average temperature."



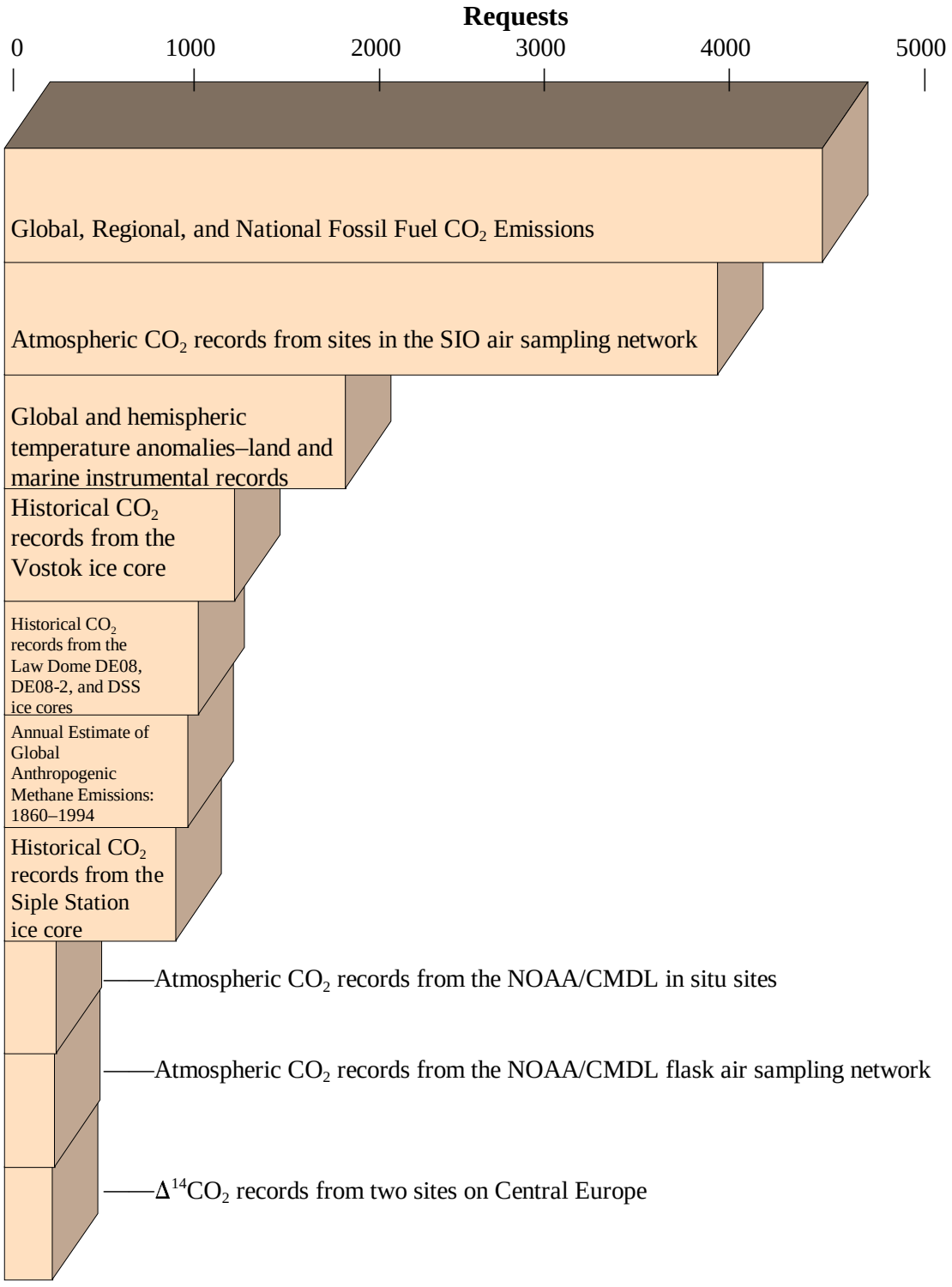
Web Visits by User Type



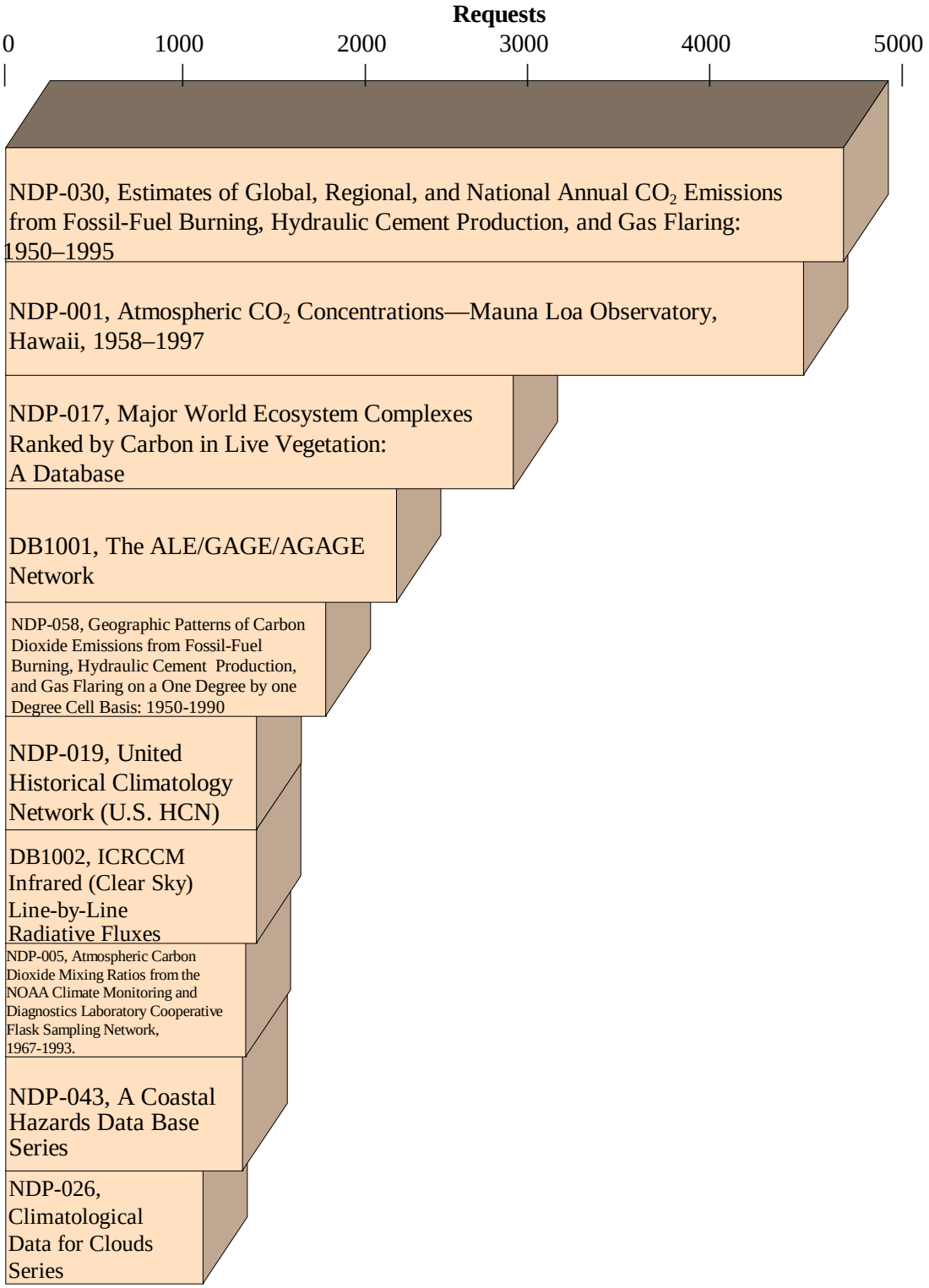
Foreign Countries Visiting CDIAC's Web Site



Most Requested *Trends Online* Records



Most Requested Web Documents



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Professional Activities

Presentations

- Boden, T. A. The Kyoto Protocol: Evaluation of Existing Data and Verification Data Requirements. Graduate political science class. Miami University, Oxford, Ohio, April 1999.

- King, A. W., and T. A. Boden. National and Global Supply Curves for Land-Use CO_2 Emissions from an Ecological Land-Use Emissions Model and National Land-Use and Land-Cover Change Statistics. Workshop on Estimating the Costs of Biological Carbon Sequestration. Cambridge, Mass., June 1999.

- Cushman, R. M., J. Beauchamp, and A. Brenkert. Validating CDIAC's Population-Based Approach to the Disaggregation of Within-Country CO_2 Emissions. Global Climate Change: Science, Policy, and Mitigation/Adaptation Strategies. Washington, D.C., October 1998.

- Cushman, R. M., T. A. Boden, M. P. Farrell, S. B. Jones, D. P. Kaiser, P. Kanciruk, E. E. Mitchell, T. R. Nelson, and R. J. Sepanski. Retrospective on CDIAC's Activities in United States–China Research on the Greenhouse Effect. Tenth Science Team Meeting of the U.S. Department of Energy and the Chinese Academy of Sciences Joint Research on the Greenhouse Effect, Beijing, China, June 1999.

- Kaiser, D. P. Decreasing cloudiness over China: An updated analysis examining additional variables. Fourth Science Team Meeting of the U.S. DOE and the China Meteorological Administration's Joint Research on Regional Climate, Beijing, China, June 1999.

- Marland, G., T. Boden, A. Brenkert, and R. J. Andres. Historical and Projected Global Greenhouse Gas Emissions. Global Climate Change: Science, Policy, and Mitigation/Adaptation Strategies. Washington, D.C., October 1998.

Publications

- Andres, R. J., D. J. Fielding, G. Marland, T. A. Boden, and N. Kumar. 1999. Carbon dioxide emissions from fossil-fuel use, 1751–1950. Tellus 51B:759–765.

- Cushman, R. M. 1999. Global climatic-change modeling and monitoring. pp. 291–298. In D. E. Alexander and R. W. Fairbridge (eds.), Encyclopedia of Environmental Science. Kluwer Academic Publishers, Dordrecht, Boston, and London.

- Cushman, R. M., J. Beauchamp, and A. L. Brenkert. 1999. Validating CDIAC's population-based approach to the disaggregation of within-country CO_2 emissions. pp. 374–385 In J. Kinsman, C. V. Mathai, M. Baer, E. Holt, and M. Trexler (eds.), Global Climate Change: Science, Policy, and Mitigation/Adaptation Strategies. Air & Waste Management Association, Pittsburgh.

- Cushman, R. M., T. A. Boden, M. P. Farrell, S. B. Jones, D. P. Kaiser, P. Kanciruk, E. E. Mitchell, T. R. Nelson, and R. J. Sepanski. 1999. Retrospective on CDIAC's activities in United States–China research on the greenhouse effect. pp. 122–127. In S.-Y. Tao, M. R. Riches, P.-Q. Chen, and W.-C. Wang (eds.), Greenhouse Effect and Climate Change. China Ocean Press, Beijing

- Marland, G., T. Boden, A. Brenkert, and R. J. Andres. 1999. Historical and projected global greenhouse gas emissions. pp. 37–42. In J. Kinsman, C. V. Mathai, M. Baer, E. Holt, and M. Trexler (eds.), Global Climate Change: Science, Policy, and Mitigation/Adaptation Strategies. Air & Waste Management Association, Pittsburgh.

- Marland, G., A. Brenkert, and J. Olivier. 1999. CO_2 from fossil fuel burning: A comparison of ORNL and EDGAR estimates of national emissions. Environmental Science and Policy 2:265–273.

Awards and Kudos

- 1999 Technical Publications Competition sponsored by the East Tennessee Chapter of the Society for Technical Communication (STC).

  Award of Merit in technical reports (conferred in February 1999)

  Surface Water and Atmospheric Underway Carbon Data Obtained During the World Ocean Circulation Experiment Indian Ocean Survey Cruises (R/V Knorr, *December 1994-January 1996)* (NDP-064) (Linda Allison and Alex Kozyr, CDIAC, and Christopher Sabine, Princeton University) (http://cdiac.esd.ornl.gov/oceans/ndp_064/ndp064.html)

  Award of Excellence in informational materials (conferred in February 1999)

  Catalog of Databases and Reports (Marvel Burtis and Karen Gibson, CDIAC) (http://cdiac.esd.ornl.gov/epubs/catalog/index.htm)

- 1998 Online Competition sponsored by the Atlanta Chapter of the Society for Technical Communication.

  Award of Merit in the web site category (conferred in April 1999).

  Terrestrial Ecology and Global Change [Terrestrial Ecological Research Initiative (TECO) Web page] (Karen Gibson) (http://daacl.esd.ornl.gov/teco/)

- **World-Class Teamwork Award** presented to Tom Boden and Karen Gibson by the Oak Ridge National Laboratory Value Awards Committee for their exceptional teamwork with Linda Armstrong, Mark Bevelhimer, and Chris Poole, all of the Environmental Sciences Division, in creating the ESD Web site.

- CDIAC is included in the World Resources Institute *Guide to Global Environmental Statistics* among "organizations that are doing the best job of identifying and locating global environmental information."

Selected Citations

Data from CDIAC publications were cited in a number of journal articles, magazine articles, and newsletters. The following publications are representative of works that have been cited.

- NDP-019 *United States Historical Climatology Network Daily Temperature, Precipitation, and Snow Data for 1871–1997* (Easterling et al.)

  Gallo, K. P., T. W. Owen, D. R. Easterling, and P. F. Jamason. 1999. Temperature trends of the U.S. Historical Climatology Network based on satellite-designated land use/land cover. *Journal of Climate* 12:1344–1348.

- NDP-021 *Historical Sunshine and Cloud Data in the United States* (Steurer and Karl)

  Croke, M. S., R. D. Cess, and S. Hameed. 1999. Regional cloud cover change associated with global climate change: Case studies for three regions of the United States. *Journal of Climate* 12:2128–2134.

- NDP-030 *Global, Regional, and National CO_2 Emission Estimates from Fossil-Fuel Burning, Cement Production, and Gas Flaring: 1751–1996* (Boden et al.)

  Houghton, R. A., J. L. Hackler, and K. T. Lawrence. 1999. The U.S. carbon budget: contributions from land-use change. *Science* 285:574–578.

- NDP-039 *Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China (Tao et al.)*

  Samel, A. N., W.-C. Wang, and X.-Z. Liang. 1999. The monsoon rainband over China and relationships with the Eurasian circulation. *Journal of Climate* 12:115–131.

- NDP-041 *The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data*

  EarthInfo, Inc. has released its "GHCN Global Climate 1998" CD-ROM, derived from CDIAC's Global Historical Climatology Network.

- NDP-042 *United States Historical Climatology Network Daily Temperature and Precipitation Data* (Hughes et al.)

  Kunkel, K. E., and K. Andsager. 1999. Long-term trends in extreme precipitation events over the conterminous United States and Canada. *Journal of Climate* 12:2515-2527.

  Stooksbury, D. E., C. G. Idso, and K. G. Hubbard. 1999. The effects of data gaps on the calculated monthly mean maximum and minimum temperatures in the continental United States: A spatial and temporal study. *Journal of Climate* 12:1524–1533.

- NDP-050 *Continental Scale Estimates of the Biotic Carbon Flux from Land Cover Change: 1850 to 1980* (Houghton and Hackler)

  Houghton, R. A., J. L. Hackler, and K. T. Lawrence. 1999. The U.S. carbon budget: Contributions from land-use change. *Science* 285:574–578.

- *Trends '93* (ORNL/CDIAC-65) and *Trends Online*

  Croke, M. S., R. D. Cess, and S. Hameed. 1999. Regional cloud cover

change associated with global climate change: Case studies for three regions of the United States. *Journal of Climate* 12:2128–2134.

Flavin, C., and S. Dunn. 1999. Reinventing the energy system. In Linda Starke (ed.), *State of the World 1999*. Norton & Company, New York and London.

Indermühle, A., T. F. Stocker, F. Joos, H. Fischer, H. J. Smith, M. Wahlen, B. Deck, D. Mastroianni, J. Tschumi, T. Blunier, R. Meyer, and B. Stauffer. 1999. Holocene carbon-cycle dynamics based on CO_2 trapped in ice at Taylor Dome, Antarctica. *Nature* 398:121–126.

- YOTO (Year of the Ocean) Drifters Web site (http://drifters.doe.gov)

Carlson, Shawn. Floating a Challenge, *Scientific American*, November 1998 (http://www.sciam.com/1998/1198issue/1198amsci.html)

- The NOPP Drifters Web site (http://drifters.doe.gov/)

Internet Scout Report for Science and Engineering, September 15, 1999. (http://scout.cs.wisc.edu/report/sci-eng/1999/se-990915.html#6).

- Carbon Dioxide Information Analysis Center (http://cdiac.esd.ornl.gov/)

World Resources Institute's Guide to Global Environmental Statistics (http://www.wri.org/statistics/)

- Trends in Total Cloud Amount Over China (http://cdiac.esd.ornl.gov/trends/clouds/kaiser/kaiser98.html)

American Meteorological Society (http://www.ametsoc.org/AMS/newsltr/nl_10_99.html#carbon)

What's Coming in FY 2000

CDIAC is working on the following new data and information products and hopes to have them available (both in printed format and online) in FY 2000. We continue to update our most popular product, *Trends Online*, and this section outlines our FY 2000 plans for the product. Lastly, this section presents our expectations for FY 2000 from a systems development and project support standpoint. Remember to check the "New" page on our Web site (http://cdiac.esd.ornl.gov/new/new.html) for announcements of the latest CDIAC products.

New Data and Information Products

- **NDP-073**
  A Database of Herbaceous Vegetation Responses to Elevated Atmospheric CO_2 (ORNL/CDIAC-120, NDP-073) by Michael Jones and Peter Curtis, The Ohio State University, and prepared by CDIAC's Bob Cushman and Antoinette Brenkert. A multiparameter database of responses by herbaceous vegetation to increased atmospheric CO_2 levels was compiled to support a statistically rigorous meta-analysis of research results across many studies. Data were retrieved from the published literature for 121 independent CO_2-enrichment studies, covering 61 species and 26 response parameters.
  Completed November 1999
  (http://cdiac.esd.ornl.gov/epubs/ndp/ndp073/ndp073.html)

- **NDP-068**
  Geographical Distribution of Biomass Carbon in Tropical Southeast Asian Forests: A Data Base by Sandra Brown, Winrock International; Louis R. Iverson, USDA Forest Service (Delaware, Ohio); and Anantha Prasad, University of Illinois; and prepared by Bob Cushman and Antoinette Brenkert, CDIAC, and Tammy Beaty, ORNL. This is the fourth database to be published by CDIAC concerning carbon fluxes to the atmosphere from tropical land-use changes. The database consists of estimates of geographically referenced carbon densities of forest soils and vegetation in tropical Asia. The vegetation carbon densities are based on potential carbon estimates, which are derived from climatic, edaphic, and geomorphic indices and vegetation and are subsequently modified on the basis of population densities, climate, and vegetation data. The soil organic carbon estimates are calculated from pedon data for tropical forests and mapped to a texture/climate map for all of tropical Asia.

- **NDP-0XX**
  Carbon-13 and Oxygen-18 Data from the NOAA Climate Monitoring and Diagnostics Laboratory Flask Sampling Network, 1990–1997, by James W. C. White and Bruce H. Vaughn, University of Colorado; Kenneth A. Masarie and Pieter P. Tans, CMDL/NOAA; and Michael Trolier, Institute of Arctic and Alpine Research (INSTAAR), and prepared by Linda Allison and Antoinette Brenkert, CDIAC. Stable isotope $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios in the atmosphere were measured, beginning in 1990 and extending through the end of 1997, as part of a joint program between INSTAAR at the University of Colorado and NOAA/(CMDL). Data represent 42 sites for ^{13}C sampling and 21 sites for ^{18}O sampling and include shipboard as well as land sampling. Data are given for all sites where at least 18 months of data are available through the end of 1997.

- **NDP-0XX**
  Carbon Dioxide, Hydrographic, and Chemical Data Obtained during the R/V Hespérides *Cruise in the Atlantic Ocean*

(WOCE Section A5, July 14–August 15, 1992), contributed by Frank Millero and Douglas M. Campbell, University of Miami; Sara Fiol, Universidad de la Coruña; and Gregorio Parrilla, Instituto Español de Oceanografía, and prepared by CDIAC's Linda Allison and Alex Kozyr. This data documentation discusses the procedures and methods used to measure total carbon dioxide (TCO_2), total alkalinity (TALK), and pH at hydrographic stations during the R/V *Hespérides* oceanographic cruise in the Atlantic Ocean (Section A5). Conducted as part of the World Ocean Circulation Experiment (WOCE), the cruise began in Cadiz, Spain, and ended in Miami, Florida.

- **NDP-0XX**
  Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V John V. Vickers *Cruise in the Pacific Ocean (WOCE Section P13, NOAA CGC92 Cruise, August 4–October 21, 1992*, by Andrew Dickson and David Keeling, SIO, and John Bullister, Pacific Marine Environmental Laboratory (PMEL), and prepared by CDIAC's Alex Kozyr. This data documentation discusses the procedures and methods used to measure total carbon dioxide (TCO_2) and total alkalinity (TALK) at hydrographic stations during the R/V *John V. Vickers* oceanographic cruise in the Pacific Ocean (Section P13). Conducted as part of the World Ocean Circulation Experiment (WOCE) and the National Oceanic and Atmospheric Administration's Climate and Global Change Program, the cruise began in Los Angeles on August 4, 1992, with transit line (Leg 0) to Dutch Harbor, Alaska. On August 16, the ship departed Dutch Harbor with occupations of stations on Leg 1 of WOCE section P13. On September 15, 1992 the R/V *John V. Vickers* arrived to Kwajalein, Marshall Islands, for emergency repairs and after 11 days in port departed for Leg 2 on September 26, 1992. The cruise ended on October 21 in Noumea, New Caledonia. Measurements made along WOCE Section P13 included pressure, temperature, salinity [measured by conductivity, temperature, and depth sensor (CTD)], bottle salinity, bottle oxygen, phosphate, nitrate, nitrite, silicate, chlorofluorocarbons (CFC-11, CFC-12), TCO_2, and TALK. The TCO_2 was measured by coulometry using a Single-Operator Multiparameter Metabolic Analyzer (SOMMA). The overall precision and accuracy of the analyses was ±2 mol/kg. Samples collected for TALK were measured by potentiometric titration; precision was ±4 mol/kg.

- **ORNL/CDIAC-115**
  Comparison of the Carbon System Parameters at the Global CO_2 Survey Crossover Locations in the North and South Pacific Ocean, 1990–1996, by R. A. Feely, M. F. Lamb, D. J. Greeley, PMEL, and R. Wanninkhof, NOAA/Atlantic Oceanographic and Meteorological Laboratory, and prepared by CDIAC's L. J. Allison and D. C. Griffith. As a collaborative program to measure global ocean carbon inventories and provide estimates of the anthropogenic carbon dioxide uptake by the oceans, NOAA and DOE have sponsored the collection of ocean carbon measurements as part of the WOCE and Ocean-Atmosphere Carbon Exchange Study cruises. The cruises discussed here occurred in the North and South Pacific from 1990 through 1996. The carbon parameters from these 30 crossover locations have been compared to ensure that a consistent global data set emerges from the survey cruises. The results indicate that for dissolved inorganic carbon, fugacity of CO_2, and pH, the agreements at most crossover locations are well within the design specifications for the global CO_2 survey; whereas, in the case of total alkalinity, the agreement between crossover locations is not as close.
  Completed December 1999
  (http://cdiac.esd.ornl.gov/oceans/pmel/pmel.html)

- *Atmospheric Methyl Chloride* by M. A. K. Khalil and R. A. Rasmussen, Oregon Graduate Institute of Science and Technology, and prepared by CDIAC's Tom Boden. This data set provides monthly average concentrations of atmospheric methyl chloride taken from seven locations distributed among the polar, middle, and tropical latitudes of both hemispheres. The seven primary sites include Pt. Barrow, Alaska; Cape Kumukahi and Mauna Loa, Hawaii; Cape Matatula, Samoa; Cape Grim, Tasmania; and the South Pole and Palmer Station, Antarctica. Concentration measurements from these seven sites cover a period of 16 years, extending from 1981 to 1997. Monthly data taken between 1987 and 1989 from 20 short-term sites and vertical distribution measured at various latitudes are also provided. Air samples were collected from various sites in stainless steel flasks and methyl chloride concentrations were measured using an Electron Capture Gas Chromatograph. Concentrations are reported as mixing ratios in dry air. The concentrations are determined by using a set of calibration standards that are referenced against a primary standard which is also used to establish the absolute concentration. The primary standards were prepared by the investigators in the absence of an available standard from a centralized location. **Completed February 2000** (http://cdiac.esd.ornl.gov/epubs/other/methylchl.html)

CDIAC Communications

- We plan to have two new issues of our newsletter available during FY 2000, the first due out in June. Look for these online (http://cdiac.esd.ornl.gov/newsletr/ccindex.html); if you let us know, we will be glad to notify you via e-mail when a new issue is online. Printed copies of *CDIAC Communications* are available on request.

Updated Data and Information Products

- **DB1001**
  The ALE/GAGE/AGAGE Network by Prinn et al. and prepared by CDIAC's Tom Boden will be updated through part of 1999. The data will be presented relative to current AGAGE calibration standards and with improved pollution analysis schemes.

- **NDP-008**
  Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958–1998 by James Angell (NOAA Air Resources Laboratory) will be updated and prepared by CDIAC's Dale Kaiser and Sonja Jones. Data from a global network of 63 radiosonde stations were used to estimate temperature deviations from 1958 through 1998. These estimates are categorized vertically (for the surface, troposphere, tropopause, low stratosphere, and the surface up to 100 mb) and horizontally (for the globe, the Northern and Southern Hemispheres, and the North and South Polar, North and South Temperate, North and South Subtropical, Tropical, and Equatorial latitudinal zones). The data were obtained from *Monthly Climatic Data for the World* and *Climatic Data for the World*, from the Global Telecommunications System (GTS) Network, and from National Center for Atmospheric Research (NCAR) files. Based on this network, Angell reported that during 1958–1998 the global, near-surface air temperature warmed by 0.14° C/decade, and the troposphere layer warmed by 0.10° C/decade. The tropopause cooled in the extratropics but warmed slightly in the tropics. The low-stratospheric layer cooled by about 0.4° C/decade in the tropics and extratropics. At both the surface and in the troposphere, 1998 was the warmest year of the 41-year record, but when the influence of the powerful El Niño of 1997–1998 on these temperatures is taken

into account, 1990 remains the warmest year of the record.
Completed October 1999
(http://cdiac.esd.ornl.gov/ndps/ndp008.html)

Note: Updated methods and trends, including graphics, for Angell's *Global, Hemispheric, and Zonal Temperature Deviations Derived from Radiosonde Records*, are also available through CDIAC's *Trends Online*. (http://cdiac.esd.ornl.gov/trends/temp/angell/angell.html)

- **ORNL/CDIAC-101**
  Publications, Presentations, and Awards by R. M. Cushman, CDIAC. This online bibliography lists CDIAC's journal articles, book and proceedings chapters, numeric data packages and online databases, other ORNL and DOE reports published by CDIAC, presentations by CDIAC staff, and awards presented to CDIAC since its establishment in 1982. This publication is available online only.
  Completed January 2000
  (http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac101/pubslist.htm)

Trends Online Update

Although CDIAC will not print a hard-copy version of *Trends* during FY 2000, we do plan to update and expand the four existing sections. The following summarizes the FY 2000 activities planned for each of these sections. We hope to add (**A**) or update (**U)** the following records:

- **Atmospheric Carbon Dioxide and Carbon Isotopes**

  U Atmospheric CO_2 records from sites in the SIO air sampling network (Keeling and Whorf)

  U Atmospheric CO_2 records from sites in the NOAA/CMDL continuous monitoring network (Thoning and Tans)

  U Atmospheric CO_2 records from sites in the NOAA/CMDL flask air sampling network (Conway and Tans)
  Completed February 2000

  U Atmospheric CO_2 record from in situ measurements at K-puszta (Haszpra)

  U Atmospheric CO_2 record from flask measurements at Lampedusa Island (Ciattoglia and Chamard)

  U Atmospheric CO_2 record from in situ measurements at Mt. Cimone (Colombo and Santaguida)

  U Atmospheric CO_2 record from in situ measurements at Baring Head (Manning et al.)

  U In situ $\delta^{13}CO_2$ from Cape Grim, Tasmania, Australia (Francey and Allison)

  U Atmospheric $\Delta^{14}CO_2$ record from Wellington, New Zealand (Manning and Melhuish)

  U $\Delta^{14}CO_2$ records from two sites in Central Europe—Schauinsland and Vermunt (Levin et al.)

- **Carbon dioxide emissions from fossil-fuel consumption**

  U Global, regional, and national fossil-fuel CO_2 emissions (Marland et al.)

- **Temperature**

  A Historic isotopic temperature record from the Vostok ice core (Petit et al.)
  Completed January 2000

  U Global and hemispheric temperature anomalies—land and marine instrumental records (Jones et al.)

  U Global, hemispheric, and zonal temperature deviations derived from radiosonde records (Angell)
  Completed October 1999

A Global and hemispheric satellite temperature records (Spencer and Christy)

- **Clouds**

U Trends in total cloud amount over China (Kaiser)

AmeriFlux

During early FY 2000 CDIAC will be busy preparing for the AmeriFlux/MODIS BIOME-BGC model validation exercise. CDIAC will prepare data submission guidance for the participating AmeriFlux sites and establish mechanisms for data transfers. Ideally CDIAC will simply "mirror" servers at the majority of participating sites. We will also need to write computer codes to automate the processing of data files containing the prescribed micrometeorological parameters submitted by the sites, perform cursory data checks, and re-format the data into common units and a standardized format for ease of use by the participating modeling groups. Programs will also need to be written to automate reading the resulting model output and generating graphics suitable for immediate posting on the AmeriFlux Web site. It is expected that roughly ten monitoring sites and ten modeling groups will participate in the exercise.

Tom Boden will attend and present CDIAC's recent data management activities at the 1999 AmeriFlux Science Team Meeting in Denver. (**October 1999**)

We expect to finalize AmeriFlux data from

Oklahoma sites (Ponca and Shidler), 1996–1997 (**February 2000**)

Walker Branch Watershed, 1995–1998 (**March 2000**)

Howland Forest, 1996–1998 (June 2000)

Park Falls, 1996–1998 (August 2000)

We expect to post preliminary AmeriFlux data from

La Selva
Morgan Monroe State Forest
Duke Forest
Florida sites
Wind River
Camp Borden

We expect the following Ameriflux Web developments

Post a FLUXNET/AmeriFlux bibliographic database with interactive capabilities

Post a master site information database with interactive capabilities

Develop capabilities to produce automated site descriptions from the master site information database

Ocean Data

CARINA, a new global-change program, has been developed to synthesize carbon dioxide data collected in the North Atlantic for the last 15 years. CARINA (CARbon In the North Atlantic) was announced by marine scientists from eleven countries at the CO_2 in the North Atlantic Workshop in Germany. CDIAC, represented at the workshop by Alex Kozyr, was named as a prime data center for preservation and distribution of this final international North Atlantic data set. This activity will complement CDIAC's role in PICES (North Pacific Marine Science Organization) working group 13 on CO_2), making CDIAC the leading data center in the world for oceanic CO_2 measurements. (http://cdiac.esd.ornl.gov/oceans/home.html)

The GLobal Ocean Data Analysis Project (GLODAP) is a cooperative effort of investigators funded for synthesis and modeling projects through NOAA, DOE and the National Science Foundation (NSF).

Cruises conducted as part of WOCE, Joint Global Ocean Flux Study (JGOFS) and NOAA Ocean-Atmosphere Exchange Study (OACES) over the decade of the 90's have generated oceanographic data of unparalleled quality and quantity. Most of the data have been reported to national archive facilities, but have not been integrated into an internally consistent global data set. GLODAP will compile that data set and examine the global distribution and inventories of oxygen, nutrients, natural and anthropogenic carbon species, natural and bomb-produced radiocarbon, and ^{13}C. These estimates will be used to infer nutrient remineralization ratios (Redfield ratios) and the rate of anthropogenic CO_2, ^{13}C and bomb ^{14}C uptake in the oceans. These estimates provide an important benchmark against which future observational studies will be compared. They also provide tools for the direct evaluation of numerical ocean carbon models.

Systems Development

Our plans for FY 2000 include developing applications that permit users to spatially and temporally sub-set some of our larger data sets. These Web accessible applications will take advantage of our recently purchased data management and analysis software. Likely candidates include the Global Historical Climate Network (GHCN) records and the Carbon Dioxide Fossil-Fuel Emissions database. In order to take fullest advantage of our sub-setting tools, we will first review our metadata holdings and the underlying standards. We plan to expand the metadata associated with each of our products and to make sure that current metadata records are complete.

Collaborations

CDIAC realizes that it would not be possible to produce global-change data and information products without the generosity and cooperation of researchers at institutions throughout the United States and around the world. In this annual report, we have noted the collaborating individuals and institutions for each product. Below are listed the many institutions that have collaborated with CDIAC in the publication of the databases and other information products described in this report.

DOE Laboratories

- Brookhaven National Laboratory

Other Federal Agencies

- NASA Goddard Institute for Space Studies
- NOAA Air Resources Laboratory
- NOAA Atlantic Oceanographic and Meteorological Laboratory
- NOAA Climate Monitoring and Diagnostics Laboratory
- NOAA National Climatic Data Center
- NOAA Ocean-Atmosphere Carbon Exchange Study
- NOAA Pacific Marine Environment Laboratory
- USDA Forest Service

State Agencies

- California Air Resources Board

Universities/Research Institutions

- Georgia Institute of Technology
- Harvard University
- Massachusetts Institute of Technology
- National Center for Atmospheric Research
- Oak Ridge Institute for Science and Education
- The Ohio State University
- Oregon Graduate Institute of Science and Technology
- Oregon State University
- Princeton University
- Scripps Institution of Oceanography of the University of California, San Diego
- State University of New York–Albany
- University of Alaska–Fairbanks
- University of Arizona
- University of California–Berkeley
- University of California–Irvine
- University of Colorado
- University of Miami
- The University of Tennessee–Knoxville
- University of Washington
- Woods Hole Oceanographic Institution

Foreign

- Arctic and Antarctic Research Institute, Russia
- Atmosphere Environment Service of Canada (has been renamed Meteorological Service of Canada)
- Baltic Sea Research Institute, Germany
- China Meteorological Administration, Beijing
- Commonwealth Scientific and Industrial Research Organisation, Australia
- Hadley Centre for Climate Prediction and Research, United Kingdom
- Institute for Marine Sciences, Germany
- Institute of Geography, China
- Instituto Español de Oceanografía
- International Science Consultants, United Kingdom
- Laboratoire de Glaciologie et Géophysique de l'Environnement, France
- Universidad de la Coruña
- University of East Anglia, United Kingdom

Acronyms and Abbreviations

AES	Atmospheric Environment Service
AGAGE	Advanced Global Atmospheric Gases Experiment
ALE	Atmospheric Lifetime Experiment
AmeriFlux	Eddy Covariance Flux Network in North, Central, and South America
ASRC	Atmospheric Sciences Research Center
BGC	biogeochemical cycle
BIOME-BGC	global biome model-biogeochemical cycle
BNL	Brookhaven National Laboratory
BOREAS	Boreal Ecosystems Atmosphere Study
CARINA	CARbon In the North Atlantic program
CDIAC	Carbon Dioxide Information Analysis Center
CIRES	Cooperative Institute for Research in Environmental Sciences
CMDL	Climate Monitoring and Diagnostics Laboratory
CMP	computer model package
CO	carbon monoxide
CO_2	carbon dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAAC	Distributed Active Archive Center
DLT	digital linear tape
DMHB	Data Management Handbook
DB	database
DOE	Department of Energy
EDGAR	Emission Database for Global Atmospheric Research
ERULF	Energy Research Undergraduate Laboratory Fellowship
ESD	Environmental Sciences Division
FACE	Free-Air CO_2 Enrichment
FTP	File Transfer Protocol
fCO_2	fugacity of carbon dioxide
FRM/FEM	Federal Reference Methods/ Federal Equivalent Methods
FY	fiscal year
GAGE	Global Atmospheric Gases Experiment
GAW	Global Atmosphere Watch
GHCN	Global Historical Climatology Network
GISS	Goddard Institute for Space Studies (NASA)
GLODAP	Global Ocean Data Analysis Project
GPP	gross primary production
GTS	Global Telecommunications Systems
HCN	Historical Climatology Network
ICRCCM	Intercomparison of Radiation Codes in Climate Models
IfMK	Institute for Marine Sciences
IG	Institute of Geography (Chinese Academy of Sciences)
INSTAAR	Institute of Arctic and Alpine Research
IOW	Institut für Ostseeforschung

IPCC	Intergovernmental Panel on Climate Change
JGOFS	Joint Global Ocean Flux Study
LAI	leaf area index
MAPS	Measurement of Air Pollution from Satellites
MIT	Massachusetts Institute of Technology
MODIS	moderate-resolution imaging spectroradiometer
NAFTA	North American Free Trade Agreement
NARSTO	(formerly) North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NDP	numeric data package
NEP	Net Ecosystem Production
NMOC	non-methane organic compound
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOPP	National Oceanographic Partnership Program
NPP	Net Primary Production
NSF	National Science Foundation
OACES	Ocean-Atmosphere Carbon Exchange Study
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
PAMS	Photochemical Assessment Monitoring Stations
pCO_2	partial pressure carbon dioxide
PDF	portable document format
PI	principal investigator
PICES	North Pacific Marine Science Organization
PMEL	Pacific Marine Environmental Laboratory
ppmv	parts per million by volume
QPHB	Quality Planning Handbook
QSMP	Quality Systems Management Plan
QSSC	Quality Systems Science Center
RAID	redundant array of independent disks
RFP	request for proposal
SIO	Scripps Institution of Oceanography
SOMMA	Single-Operator Multiparameter Metabolic Analyzer
STC	Society for Technical Communications
SUNY	State University of New York
TALK	total alkalinity
TCO_2	total carbon dioxide
TECO	Terrestrial Ecological and Global Change
UC	University of California
USDA	United States Department of Agriculture
VOC	volatile organic compound
WDC	World Data Center
WHP	WOCE Hydrographic Program
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
YOTO	Year of the Ocean

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