ORNL/CDIAC-137

Fiscal Year 2001 Annual Report

http://cdiac.ornl.gov/

Carbon Dioxide Information Analysis Center

Oak Ridge National Laboratory

ORNL/CDIAC-137

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

Fiscal Year 2001
Annual Report

Robert M. Cushman, Thomas A. Boden, Leslie A. Hook, Sonja B. Jones,
Dale P. Kaiser, Alexander Kozyr, and Tommy R. Nelson

Compiled by Carolyn R. Householder

Environmental Sciences Division

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6335
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Table of Contents

Page

Table of Contents (cont'd)

Page

List of Figures

Figure Page

1. 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 U.S. 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 levels.

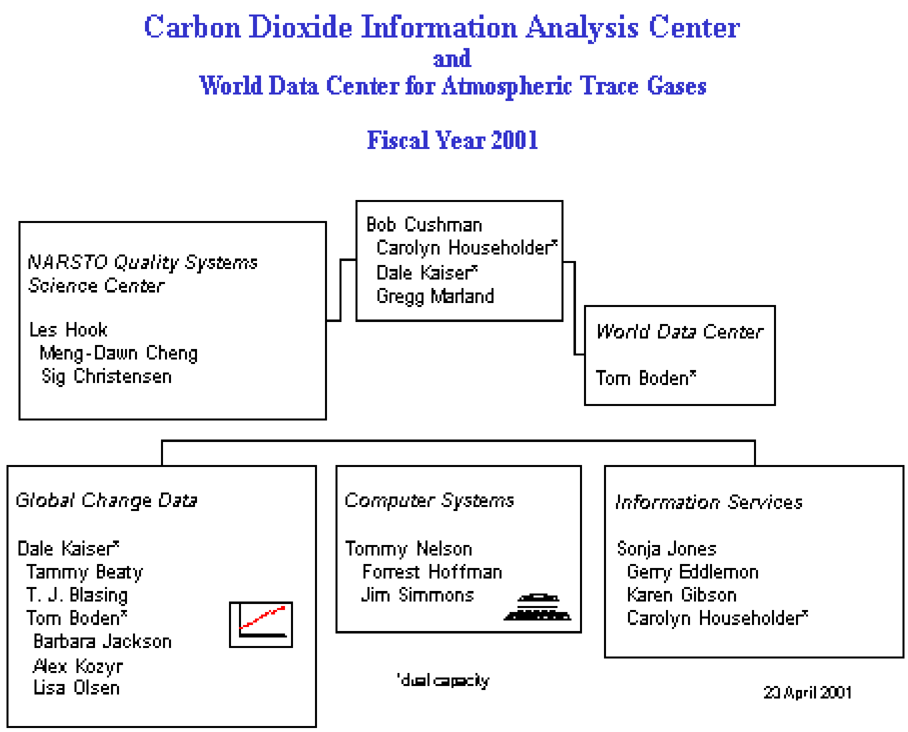
CDIAC is located within the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. CDIAC is co-located with ESD researchers investigating global-change topics, such as the global carbon cycle and the effects of carbon dioxide on climate and vegetation. 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, Director) of DOE's Office of Biological and Environmental Research. CDIAC represents DOE in the multi-agency Global Change Data and Information System (GCDIS). Wanda Ferrell is DOE's Program Manager with overall responsibility for CDIAC. Roger Dahlman is responsible for CDIAC's AmeriFlux tasks, and Anna Palmisano for CDIAC's Ocean Data tasks.

CDIAC is made up of three groups: Data Systems, Information Services, and Computer Systems, with nineteen full-time or part-time staff. The following section provides details on CDIAC's staff and organization.

- The Data Systems Group identifies and obtains databases important to global-change research; analyzes data; compiles needed databases; provides data management and support to specific programs [e.g., NARSTO, Free-Air CO_2 Enrichment (FACE), AmeriFlux, Oceans]; and prepares documentation to ensure the long-term utility of CDIAC's data holdings.
- The Information Services Group responds to data and information requests; maintains records of all request activities; analyzes user statistics; assists in Web development and maintenance; and produces CDIAC's newsletter (*CDIAC Communications*), the fiscal year annual reports, and various information materials.
- The Computer Systems Group provides computer system support for all CDIAC and WDC activities; designs and maintains CDIAC's computing system network; ensures compliance with ORNL/DOE computing security regulations; ensures long-term preservation of CDIAC data holdings through systematic backups; evaluates, develops, and implements software; ensures standards compliance; generates user statistics; provides Web design, development, and oversight; and provides systems analysis and programming assistance for scientific data projects.

1.1 Organizational Chart



1.2 Our Philosophy

Our philosophy can be expressed in terms of five interrelated principal objectives:

- Focus on the data and information products that are most in demand by our diverse user community of researchers, educators, students, policymakers, corporate officials, and the interested lay public. These products include the landmark record of rising atmospheric CO_2 at Mauna Loa, Hawaii; long-term U.S. global climate data; and global, regional, and national CO_2 emissions from fossil-fuel combustion.
- Emphasize data quality so that our understanding of global climate change is based on reliable information.
- Thoroughly document important databases so that 20 years from now, users (especially those who are not experts in the particular disciplinary area) will be able to understand how a database was produced and what the data mean.
- Provide proper credit to data contributors so that our users will understand that the data they receive from us originated not with CDIAC but rather with the investigators who so generously chose to share their data with CDIAC.
- Offer data and information to all users without restriction or charge so that society receives the greatest possible benefit from the originating research programs. Take advantage of current developments in computing technologies for data archival and distribution so that we provide a secure home for important data and provide the information to our users in the format most appropriate for them. At the same time, CDIAC appreciates that many users still prefer to receive information in more traditional formats, and we do our best to accommodate the diversity in the needs of our user community.

1.3 CDIAC Staff Listing

CDIAC Staff in FY 2001

Staff	Phone no. (Area code - 865)	Internet address (@ornl.gov)	Function
Tammy Beaty	574-0119	beatytw	Numeric Data Analyst
T.J. Blasing	574-7368	blasingtj	Physical Scientist
Tom Boden*	241-4842	bodenta	Director, WDC, Atmospheric Trace Gases; Ecologist
Meng-Dawn Cheng	241-5918	chengmd	NARSTO QSSC chief scientist
Sig Christensen	574-7394	christensen1	NARSTO data analyst
Bob Cushman	574-4791	cushmanrm	Director, CDIAC
Gerry Eddlemon	574-7337	eddlemongk	Environmental Scientist
Karen Gibson	241-4854	gibsonkn	Co-editor, CDIAC Newsletter
Forrest Hoffman	576-7680	hoffmanfm	World Wide Web specialist
Les Hook	241-4846	hookla	NARSTO QSSC Director
Carolyn Householder*	576-2118	householdecr	Information Services CDIAC Secretary
Barbara Jackson	574-8680	jacksonbl	Computer Scientist
Sonja Jones	574-3645	jonessb1	Task leader, Information Services
Dale Kaiser*	241-4849	kaiserdp	Meteorologist Task Leader, Global Change Data
Alex Kozyr	576-8449	kozyra	Oceanographer
Gregg Marland	241-4850	marlandgh	Senior scientist
Tommy Nelson[a]	574-0769	nelsontr	Task leader, Computer Systems
Lisa Olsen	241-5921	olsenlm	Geographer
Jim Simmons[b]	574-1060	simmonsjw	Workstation specialist

[a] Computational Physics and Engineering Division, ORNL
[b] Computing and Telecommunications Services, ORNL
*Dual Capacity

NOTE: Staff Listing Subject to Change-Please visit the CDIAC Web site for Staff Updates.

2. Focus Areas

2.1 AmeriFlux

(*http://public.ornl.gov/ameriflux/Participants/Sites/Map/index.cfm*)

Since 1997, CDIAC has been funded by DOE to provide data management support for the AmeriFlux network. Using the eddy-covariance (EC) method, AmeriFlux investigators measure the net flux of CO_2 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 future states, 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 involving 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 60 sites in Brazil, Canada, Costa Rica, Mexico, 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 (*http://public.ornl.gov/ameriflux/Participants/Sites/Map/index.cfm*).

The primary responsibilities of the CDIAC AmeriFlux data archive are to continually archive AmeriFlux data; examine 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 the AmeriFlux Web site.

The AmeriFlux data archive at CDIAC offers two types of data: preliminary and final. 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 generously contributed to CDIAC and made available in order to make AmeriFlux 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 PIs.

2.1.1 Noteworthy Developments During FY 2001

A prototype Web-based AmeriFlux Data Viewing and Retrieval System was completed and tested during FY 2001. The system allows users to query a network-wide AmeriFlux database by site, time, and parameter and to view results graphically. Users may also extract and download data by the same features. The initial version of the system will be made available, and the system will be further developed (e.g., additional sites, additional search criteria), during FY 2002.

A new AmeriFlux Web site was launched in July 2001. The new site generates dynamic Web pages from centralized databases shared by the AmeriFlux and FLUXNET communities. Other new features include uniform site descriptions, easier access to AmeriFlux data, and a Java-enabled map depicting past and present AmeriFlux sites.

- Tom Boden attended the AmeriFlux Science Team Meeting at Harvard Forest (October 2000).
- The CDIAC AmeriFlux archive continues to support the model and data evaluation exercise initiated during FY 2000 by Steve Running (University of Montana). CDIAC's primary role in the exercise involves processing real-time meteorological and radiation measurements from 17 AmeriFlux sites for use in models estimating site-specific gross primary production (GPP), net primary production (NPP), and NEP. Additional roles for the exercise include posting model results on a Web site developed by CDIAC for the exercise (*http://public.ornl.gov/ameriflux/model-evaluation*), providing access to MODIS satellite products, and assembling site characterization information (e.g., carbon pools, species composition, land-use histories) necessary for running the models. During each month of FY 2001, Tom Boden coordinated teleconferences among exercise participants.

2.1.2 Available Preliminary and Final AmeriFlux Site Databases

Costa Rica
- La Selva (tropical forest), 1998-2000

Canada
- Lethbridge, Alberta (mixed grass prairie), 1999-2000
- BOREAS NSA-OBS, Manitoba (old black spruce), 1994-2001
- Campbell River, British Columbia (Douglas fir), 1999
- Camp Borden, Ontario (Mixed deciduous), 1995-1997

United States
- Metolius Natural Research Area for Central Oregon (old-growth ponderosa pine), 1996-1997
- Ponca City, Oklahoma (agricultural crops, wheat), 1997-2000
- Shidler, Oklahoma (tallgrass prairie), 1997-2000
- Walker Branch Watershed, Oak Ridge National Laboratory, Tennessee (deciduous forest), 1995-1999
- Atqasuk, Alaska (moist-wet coastal sedge tundra and moist-tussock tundra), 1999-2001
- Barrow, Alaska (moist-wet coastal sedge tundra), 1998-2001
- Happy Valley, Alaska (moist, acidic tundra), 1994-1995
- Prudhoe Bay, Alaska (moist, wet sedge tundra), 1994-1995

- Blodgett Forest, California (young ponderosa pine), 1997-1998, 2000
- Sky Oaks Biological Field Station, California [chaparral, unmanaged old (78 years) and young (4 years) sites], 1997-2000
- University of Florida, Gainesville, Florida [slash pine, 24-year old stand, mid-rotation stand, and a recently clear-cut (3 year-old) stand], 1998-2000
- Niwot Ridge, Colorado (subalpine forest), 1998-2001
- Bondville, Illinois (agricultural crops, alternating corn and soybeans), 1996-2001
- Howland Forest, Maine (boreal, northern hardwood forest), 1996-1999
- Harvard Forest, Massachusetts (mixed deciduous forest), 1991-2000 EC fluxes and meteorological data; 1992-1995 hydrocarbon measurements; and 1990-1996 trace gas profiles
- Duke Forest, North Carolina (loblolly pine forest), 1997-2001
- Little Washita, Oklahoma (rangeland), 1997-1999
- Fort Peck, Montana (grassland), 1999
- Wind River Crane Site, Washington (old-growth Douglas fir forest), 1998-1999
- Park Falls, Wisconsin (lowland-wetland forest), 1996-2001
- Willow Springs Ecosystem Processes Site, Wisconsin (upland hardwood forest), 1998-2001

2.2 Free-Air CO_2 Enrichment (FACE)

(*http://cdiac.ornl.gov/programs/FACE/face.html*)

Free-Air CO_2 Enrichment (FACE) technology provides a means by which the environment around growing plants may be modified to *realistically* simulate future concentrations of atmospheric CO_2. Unlike growth chambers and greenhouses, no containment is required with FACE designs. Environmental variables that are difficult or impossible to replicate in an indoor environment, such as temperature, precipitation, wind speed, humidity, direct sunlight, and pollination, can be incorporated into the FACE experiments. In addition, the FACE program reduces or eliminates plant size or growth problems caused by the constraint of enclosures (although the system must be sized, or expandable, to accommodate the anticipated future size of the plants during the lifetime of the experiment). Therefore, long-term studies of natural communities, incorporating plants of varying ages and sizes, may be conducted. FACE field data represent plant and ecosystem responses to concentrations of atmospheric CO_2 possible during the next century in a natural setting.

FACE research technology creates a platform for multidisciplinary, ecosystem-scale research on the effects of elevated atmospheric CO_2 concentrations over extended periods of time. In doing so, a large amount and variety of high-CO_2-grown plant material can be produced to support the research of many cooperating scientists studying different aspects of an ecosystem's response to CO_2 enrichment. This concurrent use by numerous independent scientists provides the potential to gain new insights into ecosystem responses that are difficult or impossible to obtain with smaller scale, enclosed, studies.

CDIAC continued to develop its FACE Web site to support the global network of approximately thirty research sites that are operational, in development, or proposed. During FY 2001, CDIAC updated the links to, and information about, the research sites; updated the list of FACE-related publications; and provided links to news items of interest to the FACE community (including information about new FACE sites and the latest FACE research results). CDIAC has begun to format its Web and FTP sites to archive and distribute data (and accompanying documentation) from FACE research sites.

2.3 NARSTO Quality Systems Science Center (QSSC)

(*http://cdiac.ornl.gov/programs/NARSTO/narsto.html*)

The tri-national (Canada, United States, and Mexico) NARSTO program (formerly the North American Research Strategy for Tropospheric Ozone) has broadened its objectives to include atmospheric pollutants besides ozone. NARSTO is a nonbinding public/private alliance, open to science agencies, regulatory agencies, regulated industries, academic institutions, environmentalists, and public interest groups in North America. Its primary mission is to coordinate and enhance policy-relevant scientific research, and assessment 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)* (*http://cdiac.ornl.gov/programs/NARSTO/pdf/qsmp_current_version.PDF*) and the *Quality Planning Handbook (QPHB) (http://cdiac.ornl.gov/programs/NARSTO/pdf/qphb_current_version.PDF),* developed and maintained by the QSSC, provide the framework within 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)* (*http://cdiac.ornl.gov/programs/NARSTO/pdf/dmhb_current_version. PDF*) that contains metadata and data format conventions and data validation guidance. Data archive format specifications are implemented in the NARSTO Data Exchange Standard template. 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 (PDA) at the National Aeronautics and Space Administration (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.ornl.gov/programs/NARSTO/.

In addition to these quality and data management activities, the QSSC 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.ornl.gov/.

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

The FY 2001 QSSC's activities fall into three general areas: data management and archiving, data management support for projects, and external interactions.

2.3.1 Data Management and Archiving

The QSSC implemented and maintains the NARSTO Data and Information Sharing Tool (DIST). DIST is a Web-based index and clearinghouse of atmospheric measurement, chemistry data, and metadata. It can be used by a small group of investigators to securely share project data before the data are generally available, as well as allow the larger research community to locate and access data from numerous data sources in the public domain. The data in the NARSTO DIST includes results from NARSTO studies and non-NARSTO studies with data of interest to the atmospheric research community. Data are indexed using consistent metadata categories to support searching by project, location, date, keyword, investigator, etc. Projects and investigators with relevant data products (e.g., measurement data, model outputs, images, etc.) are invited to participate. Data providers can use the Web-based DIST to conveniently enter metadata and to link their data and documents into the searchable DIST index. A File Transfer Protocol (FTP) site is now associated with DIST for storage and retrieval of data sets. DIST is a key component in the flow of data from projects to the NARSTO PDA with output capabilities that facilitate metadata and data archiving.

2.3.2 Data Management Support for Projects

The QSSC provides assistance to NARSTO research managers, principal investigators, and data managers. A good example of this is our work with principal investigators from the Southern Oxidants Studies in Nashville and Atlanta, 1999.

The QSSC is also providing data management support to the U.S. Environmental Protection Agency (EPA) Particulate Matter (PM) Supersites Program. In consultation with EPA and the data coordinators of the Supersite projects, the QSSC, with the financial support of EPA, is coordinating the following activities:

1. Support for development and maintenance of a consistent set of metadata for the Supersites measurement data. Metadata are the data that describe, for measured results, the important details as to: what, where, when, how, why, and by whom. Several working groups were initially established to develop consensus on formats for site names, variable names, units, methods, and flags. Weekly teleconference discussions keep the process moving. The Supersites Program will be providing quality-assured data to the QSSC for archiving in accordance with the published NARSTO guidelines.

2. Implementation of the NARSTO DIST for the Supersites Program to support sharing of data among investigators and to use DIST's output capabilities to facilitate data archiving. The addition of new features and modifications to metadata will be made as necessary for effective implementation. The addition of new DIST users, system administration, and user support is included in this support.

3. Implementation of a Supersites FTP Site to support the sharing of data using DIST among Supersites Program participants. Supersite project data coordinators may add and maintain data on the FTP site to allow program-wide access to data, while not permitting access to secure project systems.

To address these activities in a coordinated and efficient manner, the QSSC and the Supersites working groups are utilizing the considerable technical, measurement, and data management knowledge and system resources that already exist across the Supersites projects, NARSTO, EPA, and externally. Other NARSTO, EPA, and similar atmospheric research projects are encouraged to take advantage of these results and contribute their experience and data. This coordinated effort, envisioned as a model for future cooperation, is a prime example of why NARSTO was formed and how it can function.

2.3.3 External Interactions

QSSC promotes coordination of NARSTO Data Exchange standards and automated processing programs with Bill Sukloff of Environment Canada, Meteorological Service Canada. We continue to utilize existing experts and computer software to the benefit of both programs. The QSSC cosponsored a 10-day visit by Bill Sukloff for this purpose.

2.3.4 Meetings Attended

Les Hook and Meng-Dawn Cheng represented NARSTO's QSSC at the NARSTO 2000 meeting "Tropospheric Aerosols Science and Decisions in an International Community" held in Queretaro, Mexico. Les co-chaired the Data Management/Quality session, presented "The NARSTO Data and Information Sharing Tool", and displayed a poster, "The Truth about Data Management" (both the presentation and poster were co-authored with Sigurd Christensen). Meng-Dawn presented "Real-Time Emission Measurement of Fine Particulates and Heavy Metals" (co-authored with Madhavi Martin and Thomas Wainman, also of the ORNL Environmental Sciences Division) in the session on Stationary Sources/Controls.

Les Hook and Sig Christensen attended the Third Annual Governors' Summit on Mountain Air Quality, June 1, 2001, Gatlinburg, Tennessee. Informational posters about NARSTO were displayed and copies were distributed of the recently released NARSTO publication "An Assessment of Tropospheric Ozone Pollution – A North American Perspective."

2.4 Ocean Data

(*http://cdiac.ornl.gov/oceans/home.html*)

The World Ocean Circulation Experiment (WOCE) Hydrographic Program (WHP) is a major component of the World Climate Research Program with the overall goal of better understanding 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 CO_2 is not an official WOCE measurement, a coordinated effort, supported in the U.S. by DOE, was made on WOCE cruises through 1998 to measure the global-scale and temporal distributions of total carbon dioxide (TCO_2) and 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 approximately 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. 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 2000, DOE-supported investigators had collected CO_2 measurements on 42 WOCE cruises. CDIAC has received data from 40 of these cruises, and 39 of these data sets have undergone quality assurance checks with 19 fully documented as numeric data products (NDPs). CDIAC also received carbon-related data from 6 international WOCE cruises.

CDIAC provides data management support for the GLobal Ocean Data Analysis Project (GLODAP). GLODAP is a cooperative effort of investigators funded for synthesis and modeling projects through the National Oceanic and Atmospheric Administration (NOAA), DOE, and the National Science Foundation (NSF). Cruises conducted as part of the WOCE, JGOFS, and the NOAA Ocean-Atmosphere Carbon Exchange Study (OACES) over the decade of the 1990'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 (^{14}C), 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 for comparison with future observational studies. They also provide tools for the direct evaluation of numerical models of the transport and fate of carbon in the oceans.

CDIAC provides data management support for the project CARINA (CARbon dioxide In the North Atlantic ocean). The CARINA objectives are:

- to bring together research groups that measure CO_2 in the North Atlantic Ocean;
- to create an inventory of CO_2 measurements carried out in the North Atlantic Ocean;
- to make available unpublished data to the data contributors (data access);
- to form working groups that cooperate on various aspects of the CO_2 system in the North Atlantic; and
- to exchange information concerning CO_2 research in the North Atlantic.

CDIAC also plays a major role in the CO_2 data management for the North Pacific Marine Science Organization (PICES) Working Group 13 (WG-13). The main goal of the WG-13 is to work with the data centers [Japan Oceanographic Data Center (JODC), National Oceanographic Data Center (NODC), CDIAC, Marine Environmental Data Service (MEDS), et al.] to complete an International North Pacific data set for CO_2 and CO_2-related parameters (TCO_2, total alkalinity, partial pressure carbon dioxide (pCO_2), etc.] and to encourage PICES countries (Japan, South Korea, China, Canada, Russia, and United States) and non-PICES countries to contribute data and information on data to the PICES data inventory.

3. Data and Information Products

CDIAC's carbon dioxide-related products provide data and information in several areas relevant to the greenhouse effect and global climate change. These areas include records of atmospheric trace gases [CO_2, methane, nitrous oxide, chlorofluorocarbons (CFCs), and aerosols], global carbon cycle, long-term climate records, coastal vulnerability to rising sea level, demographics, land use and ecosystems, oceanic trace gases, solar and atmospheric radiation, trace gas emissions, and vegetation response to CO_2 and climate.

CDIAC packages and distributes holdings in the form of data products [e.g., numeric data packages (NDPs), databases (DBs), and a computer model package (CMP)] and printed publications. All products are provided free of charge and are available while supplies last. Data files and documentation (text or HTML version), which accompany the data products, may be accessed and downloaded from CDIAC's Web site (*http://cdiac.ornl.gov/*), from CDIAC's anonymous FTP area (*ftp://cdiac.ornl.gov*), or requested directly from CDIAC on various types of media (e.g., CD-ROM, floppy diskette). Printed reports are available from CDIAC on request. All technical questions (e.g., methodology or accuracy) should be directed to the CDIAC staff member responsible for preparing the particular data product.

During FY 2001, CDIAC published four new NDPs and one CDIAC publication under the auspices of DOE. CDIAC updated five NDPs and one DB. CDIAC also added four new records to *Trends Online* (*http://cdiac.ornl.gov/trends/trends.htm*) and updated six existing records.

3.1 New Products

3.1.1 Land-Use & Ecosystems

- **Geographical Distribution of Biomass Carbon in Tropical Southeast Asian Forests: A Database** (ORNL/CDIAC-119, NDP-068) *http://cdiac.ornl.gov/epubs/ndp/ndp068/ndp068.html*

  Contributors*: Sandra Brown, Louis R. Iverson, Anantha Prasad, Department of Natural Resources and Environmental Sciences, University of Illinois*

  Prepared by Tammy Beaty, Lisa Olsen, Bob Cushman, and Antoinette Brenkert; March 2001.

  This database was generated from estimates of geographically referenced carbon densities of forest vegetation in tropical Southeast Asia for 1980 by providing detailed geographically referenced information on actual and potential biomass carbon (1 g biomass = 0.5 g C). A geographic information system (GIS) was used to incorporate spatial databases of climatic, edaphic (soil characteristic), and geomorphological indices and vegetation to estimate potential (i.e., in the absence of human intervention and natural disturbance) carbon densities of forests in 1980. The resulting estimates were then modified to produce a map estimating actual 1980 carbon density as a function of population density and climatic zone. The database covers the following 13 countries: Bangladesh, Brunei, Cambodia (Campuchea), India, Indonesia, Laos, Malaysia, Myanmar (Burma), Nepal, the Philippines, Sri Lanka, Thailand, and Vietnam.

The 3.75-km data in this database yield an actual total carbon estimate of 42.1 Pg (1 petagram = 10^{15} grams) and a potential carbon estimate of 73.6 Pg; whereas the 0.25-degree data produced an actual total carbon estimate of 41.8 Pg and a total potential carbon estimate of 73.9 Pg.

Brown et al. (1993) compared their estimates of biomass carbon density with those of other recent assessments for the same 13-country study area. They found that estimates of biomass carbon densities derived from the United Nations Food and Agriculture Organization (FAO) Tropical Forest Resource Assessment 1990 Project were about 75% of their own, and that estimates of 1980 biomass carbon density of Flint and Richards (1994) for forests and woodlands were about 65% of their own. Although differences exist between the estimates of Brown et al. and the other two studies, the three sets of values are similar in order of magnitude despite differences in methodology, input data, and time of assessment. The general similarity of the estimates provides compelling evidence that forests of tropical Asian countries have generally low biomass carbon densities; these low densities are most likely due to the long history of human use in the region.

3.1.2 Oceanic Trace Gases

- **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)** (ORNL/CDIAC-128, NDP-075) *http://cdiac.ornl.gov/oceans/ndp_075/ndp075.html*

  Contributors: *Andrew Dickson, Charles Keeling, and Peter Guenther (Scripps Institution of Oceanography, University of California, San Diego) and John Bullister (Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration)*

  Prepared by Alex Kozyr, CDIAC; November 2000.

  Measurements made during this WOCE cruise, which began in Dutch Harbor, Alaska, and ended in Noumea, New Caledonia, included total carbon dioxide, total alkalinity, and the chlorofluorocarbons CFC-11 and CFC-12, plus additional hydrographic and nutrient variables. This database supports studies of the transport of carbon dioxide within the ocean and movement of carbon dioxide between the ocean and atmosphere.

- **Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Knorr* Cruise 138-3, -4, and -5 in the South Pacific Ocean (WOCE Sections P6E, P6C, and P6W, May 2 - July 30, 1992)** (ORNL/CDIAC-132, NDP-077) *http://cdiac.ornl.gov/oceans/ndp_077/ndp077.html*

  Contributors: *Kenneth Johnson, Craig Neill, and Rick Wilke, Brookhaven National Laboratory; Meredith Haines, University of South Florida; Robert Key, Princeton University; Bronte Tilbrook, Commonwealth Scientific and Industrial Research Organisation; and Douglas Wallace, University of Kiel*

  Prepared by Alex Kozyr and Tammy Beaty, CDIAC; September 2001.

  Serious concern over rising atmosphere concentrations of CO_2 and consequent effects on the atmosphere's heat balance has led to increased interest in the role of the oceans in climate change and in the global carbon cycle. Increasing concentrations of greenhouse gases may intensify the earth's natural greenhouse effect and alter the climate in ways that are not well understood. Carbon in the oceans is unevenly distributed because of the complex, and therefore, poorly understood circulation patterns and biogeochemical cycles.

This database discusses the procedures and methods used to measure total carbon dioxide (TCO_2) and partial pressure of carbon dioxide (pCO_2) measured aboard the research vessel R/V *Knorr* on the three legs comprising WOCE Zonal Section P6. The section began in Valparaiso, Chile, on May 2, and ended 81 days later in Sydney, Australia, on July 20, 1992. The P6 Section was divided into three legs (P6E, P6C, and P6W) and scientists from Brookhaven National Laboratory (BNL) were responsible for the carbonate system measurements on all of these legs. Measurements made along WOCE Section P6 included pressure, temperature, salinity [measured by a conductivity, temperature, and depth (CTD) sensor], bottle salinity, bottle oxygen, silicate, nitrate, nitrite, phosphate, radiocarbon (^{14}C), TCO_2, and pCO_2.

3.1.3 Vegetation Response to CO_2 & Climate

- **Walker Branch Throughfall Displacement Experiment Data Report: Site Characterization, System Performance, Weather, Species Composition, and Growth** (ORNL/CDIAC-134, NDP-078A) *http://cdiac.ornl.gov/epubs/ndp/ndp078a/ndp078a.html*

  Contributors: *Paul Hanson, Don Todd, Gerry O'Neill, and Jeff Riggs, ORNL; Mark Wolfe, Tennessee Valley Authority*

  Prepared by Bob Cushman, CDIAC*;* July 2001.

  This numeric data package provides data sets, and accompanying documentation, on site characterization, system performance, weather, species composition, and growth for the Throughfall Displacement Experiment (TDE), which was established in the Walker Branch Watershed (WBW) of East Tennessee to provide data on the responses of forests to altered precipitation regimes. The WBW site was chosen because of its uniform slope, consistent soils, and a reasonably uniform distribution of vegetation. The forest community is dominated by white oak, chestnut oak, and red maple, but it contains more than 25 tree species. The specific data include soil water content and potential, coarse fraction of the soil profile, litter layer temperature, soil temperature, monthly weather, daily weather, hourly weather, species composition of trees and saplings, mature tree and sapling annual growth, and relative leaf area index.

  Models of global climate predict that increasing levels of greenhouse gases in the atmosphere will cause an increase in average global temperatures and alter regional levels of precipitation. Forests throughout the southeastern United States, where evapotranspiration demand is high and is predicted to increase as temperatures rise, would be particularly vulnerable to declines in annual precipitation. Potential responses of U.S. forests to future drought associated with climate change include a reduction in net primary production and stand water use, along with increased mortality of seedlings and saplings. The past 25 years of research on the WBW provide an important reference database against which to judge the outcomes of this large-scale field experiment.

3.2 Updated Products

3.2.1 Atmospheric Trace Gases

- **Atmospheric CO_2 Concentrations--Mauna Loa Observatory, Hawaii, 1958-2000 (NDP-001)** http://cdiac.ornl.gov/ndps/ndp001.html

  Contributors: *C. D. Keeling and T. P. Whorf*

  Updated by Tom Boden, CDIAC; August 2001.

  Since 1958, air samples have been continuously collected at Mauna Loa Observatory and analyzed by infrared spectroscopy for CO_2 concentrations. Data are averaged to give monthly and annual atmospheric CO_2 concentrations.

  These data represent the longest continuous record of atmospheric CO_2 concentrations in the world. This precise data record covers a single site and is a reliable indicator of the regional trend in the concentration of atmospheric CO_2 in the middle layers of the troposphere and is critical to CO_2-related research. Atmospheric CO_2 records from sites in the Scripps Institute of Oceanography (SIO) air sampling network are described in Section 3.3.1.1.

3.2.1.1 Other trace gases

- **ALE/GAGE/AGAGE (DB1001)** http://cdiac.ornl.gov/ndps/alegage.html

  Contributors: *R. Prinn, Massachusetts Institute of Technology; D. Cunnold, F. Alyea, D. Hartley, and R. H. J. Wang, Georgia Institute of Technology; P. Fraser and L. P. Steele, Commonwealth Scientific and Industrial Research Organisation; R. Weiss, Scripps Institution of Oceanography; P. Simmonds, International Science Consultants*

  Updated by Tom Boden, CDIAC; August 2001.

  In the ALE/GAGE/AGAGE global network program, continuous high-frequency gas chromatographic measurements of two biogenic/anthropogenic gases (methane, CH_4; nitrous oxide, N_2O) and six anthropogenic gases (chlorofluorocarbons $CFCl_3$, CF_2Cl_2, and $CF_2ClCFCl_2$; methyl chloroform, CH_3CCl_3; chloroform, $CHCl_3$; and carbon tetrachloride, CCl_4) are carried out at five globally distributed sites. Additional important species (H_2, CO, HFC-134a, HCFC-141b, and HCFC-142b) have been added at select sites in recent years. The program, which began in 1978, is divided into three parts associated with three changes in instrumentation: the Atmospheric Lifetime Experiment (ALE), which used Hewlett Packard HP5840 gas chromatographs; the Global Atmospheric Gases Experiment (GAGE), which used HP5880 gas chromatographs; and the present Advanced GAGE (AGAGE). AGAGE uses a new fully automated system from the Scripps Institution of Oceanography (SIO) containing a custom-designed sample module and HP5890 and Carle Instruments gas chromatographic components.

  The current station locations are Cape Grim, Tasmania; Cape Head, Ireland; and Trinidad Head, California. Stations also previously existed at Cape Meares, Oregon, and Adrigole, Ireland. The current

Mace Head station replaced the Adrigole station and the station at Trinidad Head replaced the Cape Meares station.

Presently, data from all three experiments are available through March 2001 for the five existing sites. Individual measurements (generally made 4 times daily at each site for ALE, 12 times daily at each site for GAGE, and more than 30 times daily at each site for AGAGE) and monthly summary averages are provided for each site. 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.

3.2.2 Carbon Cycle

- **Global, Regional, and National Annual CO_2 Emissions from Fossil-Fuel Burning, Cement Production, and Gas Flaring: 1751-1998 (NDP-030)** *http://cdiac.ornl.gov/ndps/ndp030.html*

  Contributors: *Gregg Marland, Tom Boden, CDIAC; and R. J. Andres, University of North Dakota*

  Updated by Tom Boden, CDIAC; July 2001.

  The global, regional, and national annual estimates of CO_2 emissions from fossil fuel burning, cement production, and gas flaring have been updated with estimates from as far back as 1751 through 1998. CO_2 emissions from fossil fuel consumption are also discussed in Section 3.3.2.1.

3.2.3 Land-Use & Ecosystems

- **Major World Ecosystem Complexes Ranked by Carbon in Live Vegetation: A Database (NDP-017)** *http://cdiac.ornl.gov/ndps/ndp017.html*

  Contributors: *Jerry Olson, Julia Watts, and Linda Allison, Environmental Sciences Division, ORNL*

  Enhanced by Bob Cushman, Sonja Jones, Dale Kaiser, and Lisa Olsen; November 2000.

  The data files now include information on medium, minimum, and maximum estimates of carbon density (in addition to latitude, longitude, ecosystem code, ecosystem name, and gridcell area). The data were reformatted by Sonja Jones, and the documentation was updated accordingly by Sonja, along with Bob Cushman and Dale Kaiser. In 1980, this database (and the corresponding map) were completed after more than 20 years of field investigations, consultations, and analyses of published literature. They characterize the use and vegetative cover of the Earth's land surface with a 0.5-degree grid. This world-ecosystem-complex database provides a current reference base for interpreting the role of vegetation in the global cycling of CO_2 and other gases and a basis for improved estimates of vegetation and soil carbon, of natural exchanges of CO_2, and of net historic shifts of carbon between the biosphere and the atmosphere.

- **Carbon Flux to the Atmosphere from Land-use Changes: 1850 - 1990 (NDP-050/R1)** *http://cdiac.ornl.gov/epubs/ndp/ndp050/ndp050.html*

  Contributors: *R. A. Houghton and J. L. Hackler, The Woods Hole Research Center, Woods Hole, Massachusetts*

  Updated by Bob Cushman, CDIAC; February 2001.

  The database documented in this NDP, a revision to a database originally published by CDIAC in 1995, consists of annual estimates, from 1850 through 1990, of the net flux of carbon between terrestrial ecosystems and the atmosphere resulting from deliberate changes in land cover and land use, especially forest clearing for agriculture and the harvest of wood for wood products or energy. The data are provided on a year-by-year basis for nine regions (North America, South and Central America, Europe, North Africa and the Middle East, Tropical Africa, the Former Soviet Union, China, South and Southeast Asia, and the Pacific Developed Region) and the globe. Some data begin earlier than 1850 (e.g., for six regions, areas of different ecosystems are provided for the year 1700) or extend beyond 1990 (e.g., fuelwood harvest in South and Southeast Asia, by forest type, is provided through 1995).

  The global net flux during the period 1850 to 1990 was 124 petagrams (Pg) of carbon. During this period, the greatest regional flux was from South and Southeast Asia (39 Pg of carbon), while the smallest regional flux was from North Africa and the Middle East (3 Pg of carbon). For the year 1990, the global total net flux was estimated to be 2.1 Pg of carbon.

3.2.4 Climate

- **Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958-1999 (NDP-008)** *http://cdiac.ornl.gov/ndps/ndp008.html*

  Contributors: *James Angell, NOAA Air Resources Laboratory, Silver Spring, Maryland*

  Updated by Sonja Jones and Dale Kaiser, CDIAC; October 2000.

  Data from a global network of 63 radiosonde stations were used to estimate temperature deviations from 1958 through 1999. 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). Based on this network, Angell reported that during 1958-1999, the global, near-surface air temperature warmed by 0.14°C/decade and the troposphere layer warmed by 0.10°C/decade. The 300-100 mb tropopause layer cooled in the extratropics but warmed slightly in the tropics. The 100-50 mb low-stratospheric layer cooled by about 0.4°C/decade in the tropics and extratropics.

3.3 *Trends Online*

3.3.1 Atmospheric Trace Gas Concentrations

3.3.1.1 Atmospheric CO_2 and carbon isotopes

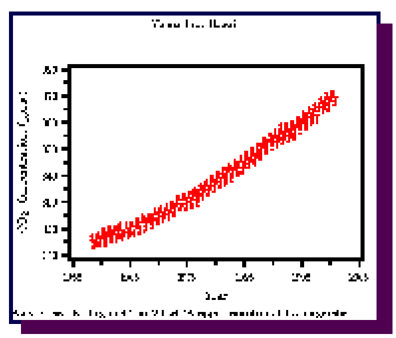
- **Atmospheric CO_2 records from sites in the SIO air sampling network**
  http://cdiac.ornl.gov/trends/co2/sio-keel.htm

  Contributors: *C. D. Keeling and T. P. Whorf*

  Updated by Tom Boden, CDIAC; August 2001.

  Ambient atmospheric CO_2 data from the Mauna Loa Observatory; Barrow, Alaska; Cape Matatula, American Samoa; and the South Pole, Antarctic have been updated with data through 2000.

  The Mauna Loa atmospheric CO_2 measurements, which began in 1958, 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 may be excluded from the records. The methods and equipment used to obtain these measurements have remained essentially unchanged during the four-decade-long monitoring program.



  The Mauna Loa record shows a 17% increase in the mean annual concentration, from 315.98 parts per million by volume (ppmv) of dry air in 1959 to 369.40 ppmv in 2000. The increase in mean annual concentration from 1999 to 2000 was 1.1 ppmv (the largest single yearly jump in the Mauna Loa record was the 2.9 ppmv increase from 1997 to 1998).

  The annual CO_2 concentration at Barrow has risen from 332.8 ppmv in 1974 to 370.73 ppmv in 2000. This represents an annual increase exceeding 1.4 ppmv per year. The Barrow record is considered indicative of maritime air masses and shows the large seasonal amplitude typical of high northerly latitude sites. At Cape Matatula, the annual average concentration of CO_2 rose from 340.6 ppmv in 1982 to 368.1 ppmv in 2000. This represents an annual growth rate of ~1.5 ppmv per year at American Samoa.

  The SIO CO_2 record from the South Pole shows that annual averages of atmospheric CO_2 concentrations rose from 314.8 ppmv in 1958 to 366.9 ppmv in 2000, representing an annual increase over 1.2 ppmv per year.

  The Mauna Loa data are also available in NDP-001.

- **Atmospheric Carbon Dioxide Record from Flask Measurements at Lampedusa Island** *http://cdiac.ornl.gov/trends/co2/lampis.htm*

  Contributors: *Paolo Chamard, Luigi Ciattaglia, Alcide di Sarra, Francesco Monteleone, Italy*

  Updated by Tom Boden, CDIAC; April 2001.

  On a rocky seashore on the eastern tip of Lampedusa Island, located south of Sicily in the central Mediterranean Sea, air samples at Lampedusa Station were collected in glass flasks each Friday from May 1992 through December 2000. On the basis of annual averages calculated from monthly averages, CO_2 levels at Lampedusa Island have risen from 360.80 ppmv in 1993 to 371.27 ppmv in 2000. The data show an average trend of +1.5 ppmv/y. The record from Lampedusa Station exhibits a typical seasonal pattern with maximum values measured during late winter or spring and minimum values recorded during the northern summer. The average annual cycle has an amplitude of about 10 ppmv. In the period of investigation the annual growth rate varies between 0.5 ppmv and 4.0 ppmv/y, and the amplitude of the annual cycle between 7 ppmv and 11 ppmv.

- **Atmospheric CO_2 record from continuous measurements at Jubany Station, Antarctica** *http://cdiac.ornl.gov/trends/co2/jubany.htm*

  Contributors: *Luigi Ciattaglia and Claudio Rafanelli, Italy; Marcelo Lombardo and Jorge Araujo, Argentina*

  Updated by Tom Boden, CDIAC; May 2001.

  The Italian PNRA (National Research Program in Antarctica) has taken continuous atmospheric carbon dioxide measurements at Jubany Station, Antarctica, since March 1994. The Jubany station is situated on King George Island, in the South Shetland archipelago north of the Antarctic Peninsula. On the basis of annual averages calculated from monthly averages running from March 1994 through December 2000, CO_2 levels at Jubany have risen from 356.75 ppmv in 1994 to 366.69 ppmv in 2000. An anomalous trend of the atmospheric CO_2 concentration was observed first during 1997-1998 at Jubany and other Antarctic stations of the World Meteorological Organization's (WMO's) Global Atmospheric Watch network. This general 1998 deceleration of the CO_2 growth rate may have been caused by several things including sea surface temperature anomalies, air temperature anomalies, and changes in general atmospheric circulation. Among all the factors affecting the atmospheric CO_2 concentration, the most convincing cause seems related to the 1997-1998 El Niño and subsequent La Niña episodes, in which the hypothesis is based on the behavior of the Southern Oscillation Index (SOI) and CO_2 concentrations at several Antarctic and non-Antarctic sites and from cross correlations between the two parameters.

3.3.1.2 Other trace gases

- **Atmospheric Fluoroform (CHF_3, HFC-23) at Cape Grim, Tasmania**
  http://cdiac.ornl.gov/trends/otheratg/oram/oram.html

  Contributors: *D. E. Oram, W. T. Sturges, and S. A. Penkett (University of East Anglia, UK); A. McCulloch (ICI Chemicals & Polymers Ltd., UK); and P. J. Fraser (Commonwealth Scientific and Industrial Research Organization, Australia)*

  Prepared by Bob Cushman, CDIAC; December 2000.

  Atmospheric fluoroform, a by-product of the manufacture of HCFC-22, has an atmospheric lifetime of 200-300 years and a global warming potential of about 10,000 times that of CO_2 on a unit-mass basis. The measured concentration of fluoroform at Cape Grim has increased from about 2 pptv (parts per trillion by volume) in early 1978 to about 11 pptv by late 1995. The current growth rate is 0.55 pptv per year over the period 1990-1995, or about 5% per year relative to the late 1995 value.

- **Trifluoromethyl Sulfur Pentafluoride (SF_5CF_3) and Sulfur Hexafluoride (SF_6) from Dome Concordia** http://cdiac.ornl.gov/trends/otheratg/sturges/sturges.html

  Contributors: *W. T. Sturges, D. E. Oram, and S. A. Penkett (University of East Anglia, UK); T. J. Wallington and M. D. Hurley (Ford Motor Company, Dearborn, Michigan); K. P. Shine and K. Sihra (University of Reading, UK); A. Engel (Johann Wolfgang Goethe University of Frankfurt, Germany); R. Mulvaney (British Antarctic Survey, UK); and C. A. M. Brenninkmeijer (Max Planck Institute for Chemistry, Germany)*

  Prepared by Bob Cushman, CDIAC; December 2000.

  A recent paper by Sturges et al. (2000) identified SF_5CF_3 as a previously unreported gas that is long-lived and with significant global warming potential (perhaps 18,000 times that of CO_2 on a unit-mass basis). The measured concentration of SF_5CF_3 increased from zero in 1965-1966 to about 0.12 pptv (parts per trillion by volume) in 1999, with a current growth rate of about 0.008 pptv per year (about 6% per year). This gas may be a breakdown product of SF_6, widely used in electrical transformers, and a by-product of the manufacture of SF_6.

3.3.2 Greenhouse Gas Emissions

3.3.2.1 CO_2 emissions from fossil-fuel consumption

- **Global, Regional, and National Annual CO_2 Emissions from Fossil Fuel Burning, Cement Production, and Gas Flaring: 1751–1998** http://cdiac.ornl.gov/trends/emis/em_cont.htm

  Contributors: *G. Marland and T. A. Boden, CDIAC; and R. J. Andres, Institute of Northern Engineering, School of Engineering, University of Alaska-Fairbanks, Fairbanks, Alaska*

Updated by Tom Boden, CDIAC; July 2001.

Global, regional, and national annual estimates of CO_2 emissions from fossil fuel burning, cement production, and gas flaring have been calculated through 1998; some of these series extend back to 1751. These estimates, derived primarily from energy statistics published by the United Nations (UN), were calculated using the methods of Marland and Rotty (1984). Cement production estimates from the U.S. Department of Interior's Bureau of Mines were used to estimate CO_2 emitted during cement production. Emissions from gas flaring were derived primarily from UN data but were supplemented with data from DOE's Energy Information Administration (Rotty 1974) and with a few national estimates provided by Gregg Marland.

3.3.3 Climate

3.3.3.1 Temperature

- **Monthly surface air temperature time series area-averaged over the 30-degree latitudinal belts of the Globe** *http://cdiac.ornl.gov/trends/temp/lugina/lugina.html*

Contributors: *K.M. Lugina, Russia, Dept. of Geography, St. Petersburg State University; P.Ya. Groisman, National Climate Data Center, Asheville, North Carolina; K.Ya. Vinnikov, University of Maryland; V.V. Koknaeva, and N.A. Speranskaya, State Hydrological Unit, St. Petersburg, Russia*

Prepared by Daria Scott and Dale Kaiser, CDIAC; August 2001.

Supplemented with information from different national publications, these mean monthly and annual values of surface air temperature have been taken mainly from the *World Weather Records, Monthly Climatic Data for the World,* and *Meteorological Data for Individual Years over the Northern Hemisphere,* excluding the former USSR. This new version of the station temperature archive (used for evaluation of the zonally-averaged temperatures) was created in 1995. The total number of stations in the Northern Hemisphere and Southern Hemisphere was 384 and 301, respectively.

Based on these mean monthly and annual surface air temperature anomaly data, it was reported that both hemispheres were warming at a rate of 0.5°C/100 yrs. The present update of the series through 1999 shows that the Northern Hemisphere has warmed at a rate of 0.6°C/100 yrs, and the Southern Hemisphere at a rate slightly greater than 0.5°C/100 yrs. The warming rate for the globe is slightly less than 0.6°C/100 yrs (0.58°C/100 yrs), a trend very close to that calculated using other well-known global data [e.g., those of NASA and the Climate Research Unit (CRU), University of East Anglia, England] compilations.

In the global records, like other records, these anomalies show that the 1980s and particularly the 1990s were much warmer than the rest of the record. In the global record, the ten warmest years have occurred since 1981. In descending order they are 1998, 1995, 1990, 1997, 1991, 1988, 1987, 1981, 1994, and 1989. The mean temperature deviation for the 1990s is 0.42°C. The warming in the 1990s is unprecedented.

- **Tropospheric and Lower Stratospheric Temperature Anomalies Based on Global Radiosonde Network Data** *http://cdiac.ornl.gov/trends/temp/sterin/sterin.html*

  Contributor: *Alexander M. Sterin, Russian Research Institute for Hydrometeorological Information-World Data Center (RIHMI-WDC), Russia*

  Prepared by Daria Scott and Dale Kaiser, CDIAC; September 2001.

  The observed radiosonde data from the Comprehensive Aerological Reference Data Set (CARDS) is known as the most complete collection of radiosonde data available and includes data for more than 2500 stations. These CARDS data were used to compute monthly mean temperature values for two atmospheric layers: the lower stratosphere (100hPa - 50hPa) and the bulk of the troposphere (850hPa - 300hPa), over the globe, the tropics (20°N - 20°S), the northern extratropics (20°N - 90°N), and the southern extratropics (20°S - 90°S). The series are updated on an annual basis. For the preliminary update, anomalies obtained from the Global Telecommunications System (GTS) global network radiosonde data collected at RIHMI-WDC were used. A more precise final update is obtained from the CARDS database when it is completed for each year. The estimates of linear trends in these temperature anomaly time series indicate strong cooling in the lower stratosphere. This cooling occurs both in the full-length time series (beginning in 1958) and in shorter time series [beginning in 1979 for comparison with the microwave sounding unit (MSU) time series].

  For the globe, the temperature trends in the lower stratosphere are -0.236°C/decade for the series beginning in 1961 and ending in 1999, and about -0.458°C/decade for the series beginning in 1979 and ending in 1999. The temperature trends in the troposphere for the globe are +0.060°C/decade for the series beginning in 1961 and ending in 1999 (+0.051°C/decade for the series beginning in 1958 and ending in 1999), and are about +0.010°C/decade for the series beginning in 1979 and ending in 1999. This slight warming trend is, to a large extent, a result of adding 1998 data, which reflect the very strong El Niño phenomenon of that year. However, for the tropospheric temperature trends over the globe estimated for the 1979-1997 series, a slight cooling (-0.03°C/decade) is found.

- **Global and hemispheric temperature anomalies--land and marine instrumental records** *http://cdiac.esd.ornl.gov/trends/temp/jonescru/jones.html*

  Contributors: *P. D. Jones, D. E. Parker, T. J. Osborn, and K. R. Briffa, United Kingdom*

  Updated by Dale Kaiser, CDIAC; July 2001.

  These global and hemispheric temperature anomaly time series, which incorporate land and marine data, are continually updated and expanded. Some of the earliest work in producing these temperature series dates back to 1986. The land portion of the database from which the time series are computed consists of surface-air temperature (SAT) data (land-surface meteorological data and fixed-position weather ship data) that have been corrected for nonclimatic errors, such as station shifts and/or instrument changes. The most recent reanalysis of land surface data by the Climatic Research Unit (CRU) resulted in (1) the inclusion of more than 1000 additional stations, (2) a new reference period common to all stations (1961–1990; previously 1950–1979), and (3) increased grid-box resolution of the temperature anomalies

(5° × 5°). The marine data used in the present analysis are compiled at the Hadley Centre of the United Kingdom Meteorological Office and consist of sea surface temperatures (SSTs) that incorporate in situ measurements from ships and buoys. The SST data have been corrected to eliminate effects of using different types of buckets used before 1942. These SSTs also were converted to anomalies with respect to the 1961–1990 mean, and the two constituent data sets (SAT and SST) were combined.

The resulting data set has been used extensively in Intergovernmental Panel on Climate Change (IPCC) reports in which 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. From this point onward, another rapid rise similar to that in the earlier part of the century is observed. The year 1998 was the warmest of the global mean temperature series to date; the second warmest was 1997. The anomaly for 1998 was 0.57°C above the 1961-1990 reference-period mean temperature. [Jones et al. (1999)] report the 1961-1990 reference period means for the globe, northern hemisphere, and southern hemisphere as 14.0°C, 14.6°C, and 13.4°C, respectively.) The most recent year of the record, 2000, also saw a significant positive temperature anomaly (0.29°C) but represents a cooling compared with the recent very warm years of 1997 and 1998. Still, 2000 ties 1991 for the sixth warmest year in the global record, and the eight warmest years of the global record have all occurred since 1990. These are, in descending order, 1998, 1997, 1995, 1990, 1999, (2000 and 1991 - tie), and 1994. The findings of Jones and Briffa (1992) still offer a good general description of the full period of record at this point: the average surface air temperature has warmed ~0.5°C since the middle of the nineteenth century. In addition, Briffa and Jones (1993) and Nicholls et al. (1996) (which made use of all but the last few years of the record described herein) concluded that the warming has varied in extent and magnitude across the globe and a few areas have even cooled since the nineteenth century. More recent analyses of the temperature data include Jones et al. (1999; 2001).

- **Global, hemispheric, and zonal temperature deviations derived from radiosonde records**
  http://cdiac.ornl.gov/trends/temp/angell/angell.html

  Contributors: *James Angell, NOAA Air Resources Laboratory, Silver Spring, Maryland*

  Updated by Sonja Jones and Dale Kaiser, CDIAC; October 2000.

3.4. Newsletters, Reports, and Additional Online Publications

- ***CDIAC Communications.*** **Issue Number 28**
  http://cdiac.ornl.gov/newsletr/may2001/ccmay01.pdf

  Edited by Sonja Jones and Karen Gibson, CDIAC; May 2001.

  CDIAC published the Winter 2000 issue (#28) of CDIAC's newsletter "*CDIAC Communications*". This issue featured a lead story on "Carbon Emitted, Carbon Saved" and described global change databases and other publications released by CDIAC.

- **Fiscal Year 2000 Annual Report (ORNL/CDIAC-133)**
  http://cdiac.ornl.gov/epubs/cdiac/cdiac133/AnnualRpt2000.html

  Contributors: *R. M. Cushman, Thomas A. Boden, Leslie A. Hook, Sonja B. Jones, Dale P. Kaiser, Alexander Kozyr, and Tommy Nelson, CDIAC*

  Prepared by Carolyn Householder and Sonja Jones, CDIAC; August 2001.

  The report documents highlights from the fiscal year (new data products and other publications); provides information on CDIAC Focus Areas; provides statistics, such as the number of requests for global change data and information from CDIAC and citations in the published literature of data obtained from CDIAC; alerts users to new data products that CDIAC hopes to release in FY 2001; 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 2000.

3.5 What's Coming in FY 2002

CDIAC is currently working on, or has completed, the following new or existing data and information products for FY2002.

- Publications, Presentations, and Awards - updated December 2001
- Graduate Student Theses Supported by DOE's Environmental Sciences Division: Fiscal Year 2001 Update - updated February 2002
- Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Meteor* Cruise 28/1 in the South Atlantic Ocean (WOCE Section A8, March 29 - May 12, 1994) (ORNL/CDIAC-135, NDP-079) - completed March 2002

CDIAC continually expands *Trends Online* with new records and updates to existing records.

Remember to check the "New" page on our Web site (*http://cdiac.ornl.gov/new/new.html*) for announcements of the latest CDIAC data and information products.

- Tropical Africa: Land Use, Biomass, and Carbon Estimates (NDP-055) - enhanced March 2002
- Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958-2001 (NDP-008) - updated April 2002
- A Databank of Antarctic Surface Temperature and Pressure Data (NDP-032) - updated October 2001
- Atmospheric CO_2 Concentrations--Mauna Loa Observatory, Hawaii, 1958-2001 (NDP-001) - updated June 2002
- Global, Regional, and National Annual CO_2 Emissions from Fossil-Fuel Burning, Cement Production, and Gas Flaring: 1751-1998 (NDP-030) - revised July 2001
- CO_2 and weather-related FACE data from the ORNL FACE site - added June 2002 and October 2001

4. Information Services

4.1 FY 2001 Statistics

Statistics reflecting CDIAC's FY 2001 Web activity were calculated using data generated by Sane Solutions, LLC, Web log analysis tool, NetTracker®. While CDIAC continues to receive and respond to users via traditionalmethods (e.g., email, mail, fax, telephone) and users continue to access data products through direct FTP, statistics from these areas are minuscule in comparison to statistics generated from the activity on CDIAC's Web site.

In FY 2001, more than 240,500 unique hosts visited CDIAC's Web site (Figure 4.1) utilizing 340 browsers. The browsers of choice were the various versions of Microsoft Internet Explorer, Netscape Navigator, and America Online, respectively.

During FY 2001, CDIAC's Web site received more than 430,000 visits with users viewing over 2,641,000 Web pages (Figure 4.2). These statistics reflect an approximate 50 % increase in CDIAC Web traffic in FY 2001 over Web traffic in FY 2000, where 1,735,000 Web pages were viewed during 250,000 visits. The average number of pages accessed per day in FY 2001 increased from 4,754 to 7,268, while the average length of a visit to CDIAC's Web site remained at 15 minutes. [A view as defined by NetTracker® is a hit to a Web page, excluding user defined files (CDIAC excludes such files as .jpg, .gif, etc.) and a visit is defined as a series of consecutive views of a web site by the same unique host within a specified period of time. (Because the number of visits are calculated using complex algorithms, these figures are considered estimates).

Visits to CDIAC's Web site were made from 112 different domains (Figure 4.3) with the top domain being the U.S. Commercial sector. Of these 112 domains, 103 domains represented hosts from foreign countries (Figure 4.4).

An analysis by Net Tracker® of hosts and their individual paths (path being defined as the first three consecutive pages viewed by a Web site visitor) on the CDIAC Web site indicates that users entering the CDIAC Web site accessed CDIAC material via the "Search," "Products," "Trends," "WDC," "About," and "Top 10," respectively.

Major keywords used to locate CDIAC data and information products via online search engines (e.g., Yahoo, google.com, AltaVista, msn.com, Excite, Lycos, netscape.com) are:
- carbon dioxide,
- greenhouse effect,
- carbon,
- CO2,
- cdiac,
- carbon dioxide emissions,
- global warming.

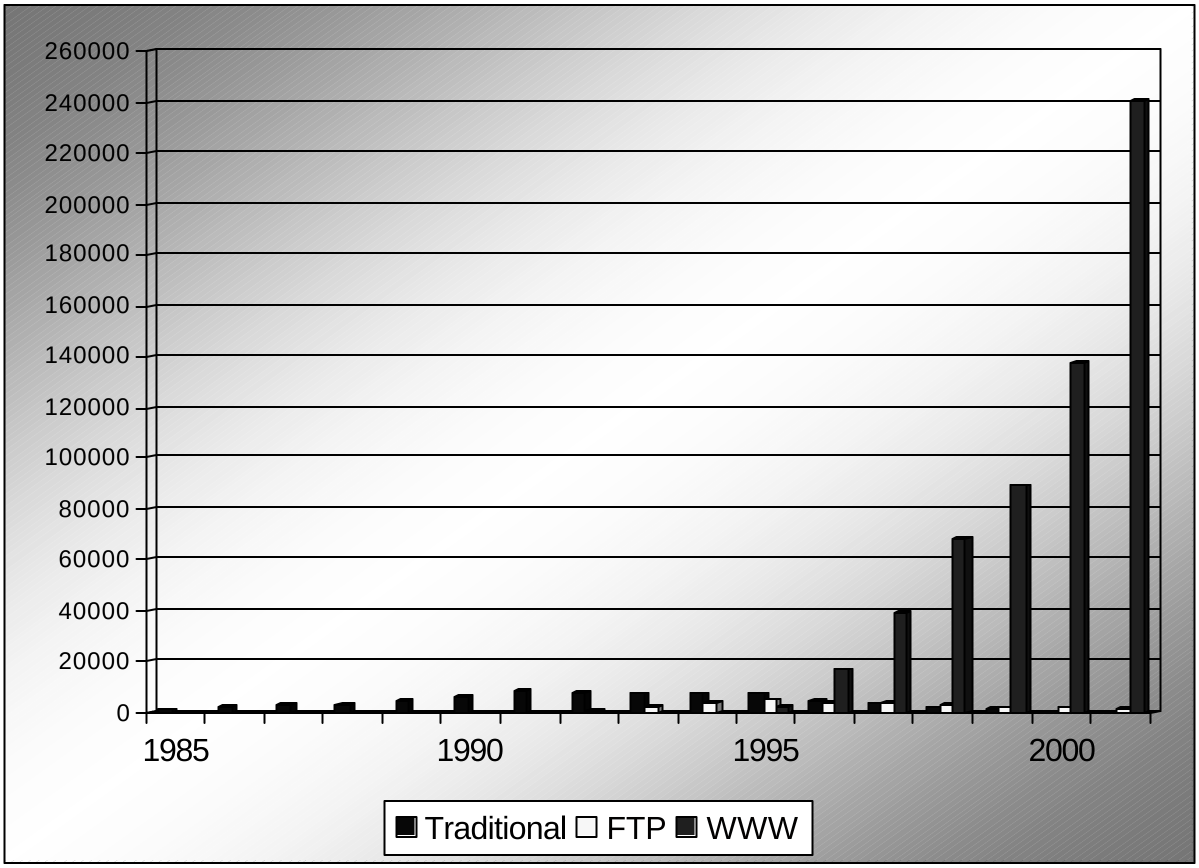


Figure 4.1 Request Activity, FY 1985 - FY 2001

CDIAC's Audience of Worldwide Users

- Educators (teachers, professors)
- Students (elementary, high school, college graduate and undergraduate)
- General Public (interested citizens, special interest groups)
- Specialists (scientists, engineers, business and industry)
- Government (legislative assistants, policymakers, agencies)
- Media (radio, television, newspapers)

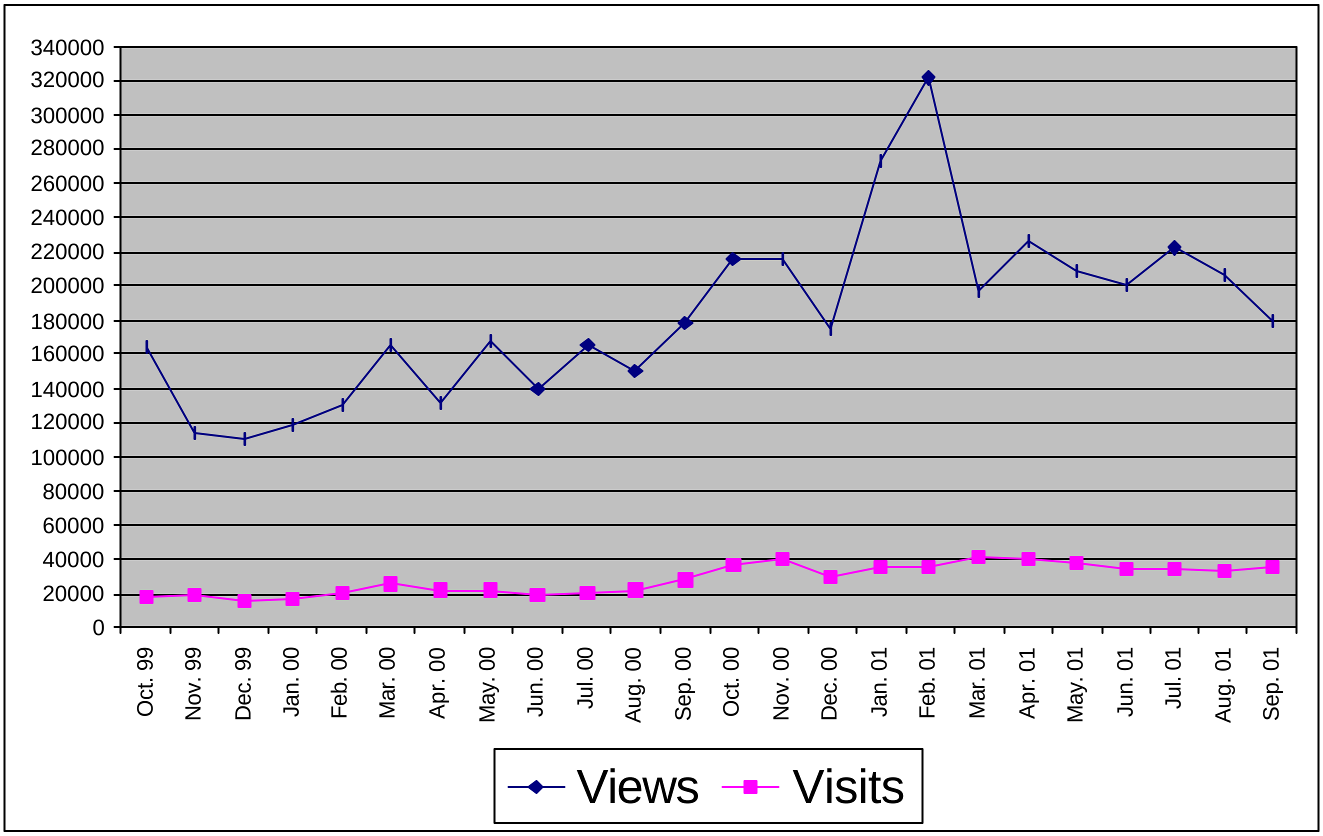


Figure 4.2 Comparison of Views/Visits for FY 2000 through FY 2001

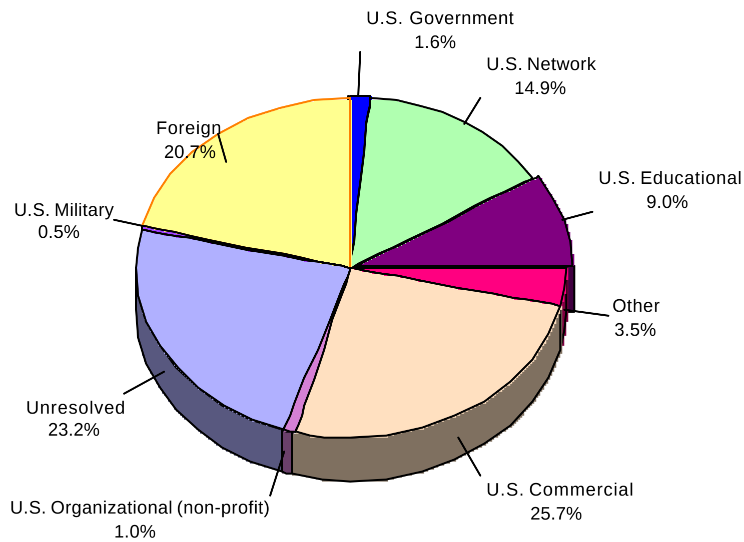


Figure 4.3 Analysis of Web Site Visits by User Domain

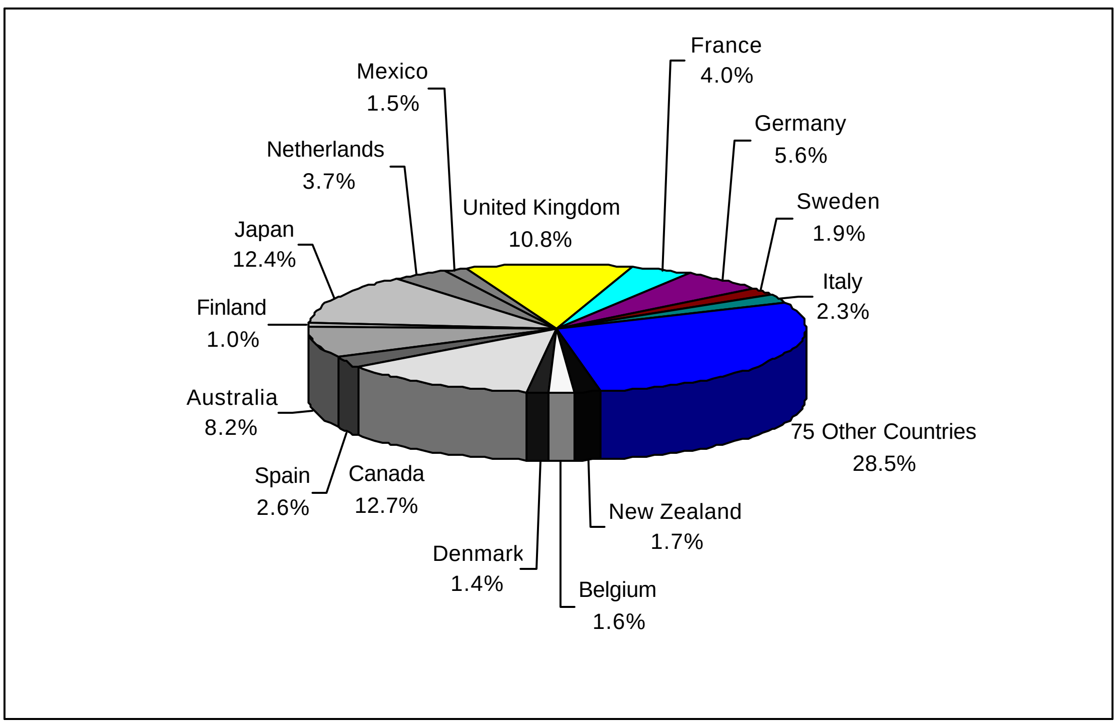


Figure 4.4 Analysis of Web Site Visits Representing Foreign Countries

5. Computer Systems Development

CDIAC's computer systems development team continues to search for ways to improve our operation and increase efficiency. To keep pace with the proliferation of data and increasing global interest in climate change data, we must continue to anticipate the impact of emerging information technologies and position ourselves to apply those technologies to meet the needs of our global user community.

5.1 Infrastructure Improvements

5.1.1 Desktop Development/Analysis Platform

We implemented the hardware/software suite chosen to replace our aged desktop hardware. We replaced all CDIAC desktop systems with a cost-effective combination providing tremendous flexibility. The new desktop systems consist of the Linux operating system, Intel® hardware, VMware®, and Windows 2000®. VMware® is a thin software layer that sits between the hardware architecture and the operating system, creating a virtual machine and managing all hardware resources. This software allows us to run any version of Microsoft Windows®, from Windows 3.1® to Windows 2000®, as a guest operating system. This configuration affords us the features and security of a UNIX®-based operating system while allowing us to utilize Windows-based tools and test our products in various Windows® environments. One attractive feature VMware® provides is the ability to move in and out of applications across the different operating systems without rebooting. Migration to the new desktop systems was completed mid-year, and we have been pleased with the results to date.

5.2 Carbon Sequestration Web Server

We continue to operate the server for the Carbon Sequestration Web site, at the request of DOE program management. In FY 2001, this Sun workstation based system received over 200,000 requests and averaged 550 visits per day from countries around the world.

5.3 World Directory User Interface

Since its inception in 1982, CDIAC has maintained a World Directory of users in order that we may easily provide information regarding new products, updates, and corrections as necessary. Information contained in the CDIAC World Directory has been voluntarily provided by users and is not distributed to any other agencies or individuals.

In order to keep CDIAC's directory information as current as possible, we began development of a new service to allow users to add their information to the directory, or modify their existing information as contained in the directory. Since we verify and confirm all additions or changes to the directory, only users with a valid e-mail of record will be permitted to modify their information via the Web. As part of this feature, we will also provide a blind e-mail service to facilitate consensual communication between researchers, educators, students, and others sharing this common interest. We made significant progress on the development of this feature and expect to complete development and implementation in FY 2002.

5.4 CDIAC Implementation of the Mercury Data Search/Retrieval System

We began development of a CDIAC implementation of Mercury. Mercury, developed at ORNL, is a data search and retrieval system that utilizes metadata to perform very accurate searches. Mercury will provide our users with sophisticated data search tools, including browse trees and dynamic pick lists. In addition to these tools, the CDIAC implementation of Mercury will provide tools to perform spatial and temporal data searches. Mercury offers but one example of the benefits to be derived from implementation of CDIAC's new metadata standard. The CDIAC prototype system was completed and beta testing was initiated. Beta testing brought to light several areas where the CDIAC implementation of Mercury would benefit from minor metadata modifications. We will perform the metadata modifications to existing metadata files and rewrite the CDIAC ORNL Metadata Editor (OME) to incorporate and automatically apply these modifications to new metadata files at the time of creation.

5.5 CDIAC OME Metadata Tools

There are many new, rapidly developing information management tools designed to help users accurately locate pertinent data while eliminating extraneous information. These tools, typically based on XML (eXtensible Markup Language), require complete and accurate metadata to be useful. To take full advantage of these tools at CDIAC, we created and implemented a new metadata standard (.met) in FY 2000. While being legible and readily understandable by humans, our new standard is compliant with the Federal Geographic Data Committee (FGDC) metadata content standard and will work well with evolving XML-based tools. This year, we worked with the Distributed Active Archive Center (DAAC) staff to develop a tool for CDIAC based on the OME. This new tool (the CDIAC OME) expedites metadata generation by providing user-friendly metadata collection forms, via a dynamic interface, for the input and modification of metadata. We also developed tools to automatically generate .xml files from existing CDIAC .met files. We used this tool to create .xml files for each of CDIAC's data products. These .xml and .met files were placed in the CDIAC ftp area along with the data files for each product. These .xml metadata files will make CDIAC data much more visible through Internet indexing services and will improve the accuracy of those services.

5.6 Computer Systems Maintenance and Updates

We also spent a considerable amount of time performing necessary routine functions in support of the CDIAC Computing System Network. These tasks included backing up nightly, upgrading/replacing disk drives, creating new file systems, installing/upgrading application software and operating system enhancements, restoring user-deleted files, installing/replacing uninterruptible power supply (UPS), responding to a wide variety of CDIAC staff calls for help, producing Web statistics, making wholesale Web changes (i.e., path changes), providing Web design direction, and maintaining the Web development area.

5.7 Plans for FY 2002

Based on system improvements implemented at CDIAC, we are well positioned to take full advantage of evolving computing and information management technologies. We have plans to build upon several new information management tools under continuing development at ORNL. We are excited by what these tools will offer our user community and look forward to a productive year in FY 2002.

We will work to complete implementation of the CDIAC OME. We plan to make the CDIAC OME available to all CDIAC staff via the Web. This will expedite metadata generation by providing a dynamic interface for the input and modification of metadata. This will encourage staff to keep product metadata current and to create proper metadata as new products are developed. Additionally, we will implement several minor modifications that will benefit the CDIAC implementation of Mercury. Proper use of metadata files and standards will make CDIAC data much more visible through Internet indexing services and will improve the accuracy of those services. We will complete implementation of the CDIAC version of Mercury.

We will complete the implementation of the World Directory User Interface. This system provides a Web interface whereby users can add themselves or modify their entries in the CDIAC World Directory. This product will feature an e-mail validation routine for user modifications, and requires staff validation of all new entries. In addition to the functional specifications originally defined, the system will be expanded to perform necessary functions previously accomplished via the Request Response Record (R^3) system. This will allow us to eventually remove the long-lived R^3 system from production. The system will provide an exclusive set of CDIAC staff functions. This will allow CDIAC staff to perform extensive ad hoc queries of the data and perform data modifications without requiring specific knowledge of the underlying data structure or structured query language (SQL) language. The system will also provide CDIAC staff with the capability to generate mailing labels and lists via Microsoft Access® and Open Database Connectivity (ODBC) drivers.

6. CDIAC Presentations, Publications, and Awards

6.1 Presentations

- Kaiser, D. P. "Assessing observed temperature and cloud amount trends for China over the last half of the twentieth century: What can the sunshine duration record tell us?" at the Science Team Meeting of the United States and People's Republic of China Joint Agreement on Global and Regional Climate Change (see *http://www.er.doe.gov/production/ober/doeprc.html*), Washington, D.C., June 2001.

- Kozyr, A. Part of a multi-institution synthesis team of oceanographers presenting posters at The Oceanography Society's Biennial Scientific Meeting (Miami Beach, Florida). "Organic Carbon Remineralization and Calcium Dissolution in the North Pacific Ocean" was presented by R. A. Feely of the Pacific Marine Environmental Laboratory (PMEL), Seattle; C. L. Sabine of the University of Washington, Seattle; K. Lee of the Atlantic Ocean Marine Laboratory (AOML), Miami; F. J. Millero of the University of Miami; M. F. Lamb and J. L. Bulister (PMEL); R. M. Key of Princeton University; R. Wanninkhof and T.-H. Peng (AOML); and Kozyr. "Anthropogenic Tracers in the Pacific Ocean" was presented by Sabine, Key, Bullister, Feely, Lamb, Millero, Wanninkhof, Peng, Lee, and Kozyr. January 2001.

- Kozyr, A. Attended the PICES (the North Pacific Marine Science Organization) CO_2 Data Integration Test Workshop, Sidney, British Columbia, Canada. Participated in discussions on the synthesis of ocean CO_2 data from the North Pacific region. January 2001.

- Kaiser, D. P. "Assessing Observed Temperature and Cloud Amount Trends for China Over the Last Half of the Twentieth Century: What Can the Sunshine Duration Record Tell Us?" 81st Annual Meeting of the American Meteorological Society and 12th Symposium on Global Change and Climate Variations, Albuquerque, New Mexico, January 2001.

- Hook, L. "The NARSTO Data and Information Sharing Tool." NARSTO 2000 Meeting, Tropospheric Aerosols: Science and Decisions in an International Community. Queretaro, Mexico, October 2000.

- Cheng, M. D., "Real-Time Emission Measurement of Fine Particulates and Heavy Metals." NARSTO 2000 Meeting, Tropospheric Aerosols Science and Decisions in an International Community. Querétaro, Mexico, October 2000.

- Kozyr, A. The new CDIAC data access, through Web maps, and the new CDIAC - World Ocean Circulation Experiment (WOCE) Collection created using the Ocean Data View Program. Symposium on North Pacific CO_2 Data Synthesis, Tsukuba, Japan. October 2000.

- Marland, G. Presented "The Increasing Concentration of Atmospheric CO_2: How Much, When, and Why?" (co-authored with Tom Boden) at the 26th Erice International Seminar on Planetary Emergencies in Erice, Sicily, Italy. The paper examines the evidence that the observed increasing atmospheric concentrations of carbon dioxide have been caused by man-made emissions. October 2000.

6.2 Publications

- Lamb, M. F., C. L. Sabine, R. A. Feely, R. Wanninkhof, R. M. Key, G. C. Johnson, F. J. Millero, K. Lee, T.-H. Peng, A. Kozyr, J. L. Bullister, D. Greeley, R. H. Byrne, D. W. Chipman, A. G. Dickson, C. Goyet, P. R. Guenther, M. Ishii, K. M. Johnson, C. D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D. W. R. Wallace, Y. Watanabe, C. Winn, and C. S. Wong. 2001. "Consistency and Synthesis of Pacific Ocean CO_2 survey data." *Deep-Sea Research,* 11 49:21-58, 2001.

6.3 Awards and Kudos

- CDIAC received four merit awards from the Society for Technical Communications/East Tennessee Chapter in its annual competitions.

  - In the online communications competition, the CDIAC Web site (*http://cdiac.ornl.gov/*) and the newsletter "*CDIAC Communications*" (*http://cdiac.ornl.gov/newsletr/ccindex.html*) received awards.

  - In the technical publications competition, the "CDIAC and WDC-A for Atmospheric Trace Gases Fiscal Year 1999 Annual Report" (*http://cdiac.ornl.gov/epubs/cdiac/cdiac126/99annual.pdf*) and "Selected Translated Abstracts of Chinese-Language Climate Change Publications" (*http://cdiac.ornl.gov/epubs/cdiac/cdiac117/cdiac117.html*) received awards.

- CDIAC's Web site (*http://cdiac.ornl.gov*) has been selected as a featured site in the StudyWeb (*http://www.studyWeb.com/*) online listing of educational resources on the Web.

7. Selected CDIAC Citations

The following citations are examples of how CDIAC products are used and cited.

NDP-001 (Keeling and Whorf)

Feely, R. A., C. L. Sabine, T. Takahashi, and R. Wanninkhof. 2001. Uptake and storage of carbon dioxide in the ocean: The global CO_2 survey. *Oceanography* 14:18-32.

NDP-017 (Olson et al.)

Dauncy, G., and P. Mazza. 2001. *Stormy Weather: 101 Solutions to Global Climate Change*. New Society Publishers, Gabriola Island, British Columbia, Canada.

NDP-039 (Tao et al.)

Wang, J. X. L., and D. J. Gaffen. 2001. Late-twentieth-century climatology and trends of surface humidity and temperature in China. *Journal of Climate* 14:2833-2845.

NDP-046 (Richards and Flint)

Ramankutty, N., K. K. Goldewijk, R. Leemans, J. Foley, and F. Oldfield. 2001. Land cover change over the last three centuries due to human activities. *Global Change Newsletter* No. 47, pp. 17-19.

NDP-048 (Razuvaev et al.)

Sun, B., P. Ya. Groisman, and I. I. Mokhov. 2001. Recent changes in cloud-type frequency and inferred increases in convection over the United States and the Former USSR. *Journal of Climate* 14(8):1864-1880.

NDP-072 (Curtis)

Gurevitch, J., P. S. Curtis, and M. H. Jones. 2001. Meta-analysis in Ecology, pp. 199-247. In H. Caswell (ed.), *Advances in Ecological Research*, Vol. 32. Academic Press, San Diego.

NDP-073 (Jones and Curtis)

Gurevitch, J., P. S. Curtis, and M. H. Jones. 2001. Meta-analysis in Ecology, pp. 199-247. In H. Caswell (ed.), *Advances in Ecological Research*, Vol. 32. Academic Press, San Diego.

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

Baldocchi, D., E. Falge, L. Gu, R. Olson, D. Hollinger, S. Running, P. Anthoni, Ch. Bernhofer, K. Davis, R. Evans, J. Fuentes, A. Goldstein, G. Katul, B. Law, X. Lee, Y. Malhi, T. Meyers, W. Munger, W. Oechel, K. T. Paw U, K. Pilegaard, H. P. Schmid, R. Valentini, S. Verma, T. Vesala, K. Wilson, and

S. Wofsy. 2001. FLUXNET: A new tool to study the temporal and spatial variability of ecosystem-scale carbon dioxide, water vapor, and energy flux densities. *Bulletin of the American Meteorological Society* 82:2415-2434.

Dauncy, G., and P. Mazza. 2001. *Stormy Weather: 101 Solutions to Global Climate Change*. New Society Publishers, Gabriola Island, British Columbia, Canada.

Osborne, C. P., and F. I. Woodward. Biological mechanisms underlying recent increases in the NDVI of Mediterranean shrublands. *International Journal of Remote Sensing* 22:1895-1907.

Schimel, D. S., J. I. House, K. A. Hibbard, P. Bousquet, P. Ciais, P. Peylin, B. H. Braswell, M. J. Apps, D. Baker, A. Bondeau, J. Canadell, G. Churkina, W. Cramer, A. S. Denning, C. B. Field, P. Friedlingstein, C. Goodale, M. Heimann, R. A. Houghton, J. M. Melillo, B. Moore III, D. Murdiyarso, I. Noble, S. W. Pacala, I. C. Prentice, M. R. Raupach, P. J. Rayner, R. J. Scholes, W. L. Steffen, and C. Wirth. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. *Nature* 414:169&172.

Woodward, F. I. 2001. Discriminating plants. *Science* 291:2562-2563.

ORNL/CDIAC-70 (Strain and Cure)

Gurevitch, J., P. S. Curtis, and M. H. Jones. 2001. Meta-analysis in Ecology, pp. 199-247. In H. Caswell (ed.), *Advances in Ecological Research*, Vol. 32. Academic Press, San Diego.

CDIAC's World-Wide-Web Site (http://cdiac.ornl.gov)

Dauncy, G., and P. Mazza. 2001. *Stormy Weather: 101 Solutions to Global Climate Change*. New Society Publishers, Gabriola Island, British Columbia, Canada.

8. CDIAC 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. Listed below are the many institutions that have collaborated with CDIAC in the publication of the databases and other information products described in this report.

8.1 DOE Laboratories

- Brookhaven National Laboratory

8.2 Other Federal Agencies

- NOAA Air Resources Laboratory
- NOAA Atlantic Oceanographic and Meteorological Laboratory
- NOAA Climate Monitoring and Diagnostics Laboratory
- NOAA Pacific Marine Environmental Laboratory

8.3 Universities/Research Institutions

- Georgia Institute of Technology
- Lamont-Doherty Earth Observatory of Columbia University
- Massachusetts Institute of Technology
- Monterey Bay Aquarium Research Institute
- National Institute for Global Environmental Change (NIGEC) National Office (University of California, Davis)
- Ohio State University
- Oregon Graduate Institute of Science and Technology
- Portland State University
- Princeton University
- Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
- Scripps Institution of Oceanography (SIO), University of California, San Diego
- University of California, Berkeley
- University of Hawaii
- University of Nebraska - Lincoln
- University of North Dakota
- University of South Florida
- Woods Hole Oceanographic Institution

8.4 Foreign Collaborators

- Arctic and Antarctic Research Institute, Russia
- Commonwealth Scientific and Industrial Research Organisation, Australia

- Hadley Centre for Climate Prediction and Research, United Kingdom
- Institute of Geography, Russia
- Institute of Ocean Science, Canada
- Instituto Español de Oceanografía, Spain
- International Science Consultants, United Kingdom
- Laboratoire de Glaciologie et Géophysique de l'Environnement, France
- Laboratoire des Sciences du Climat et de l'Environnement, France
- University of East Anglia, United Kingdom

9. Acronyms and Abbreviations

AGAGE	Advanced Global Atmospheric Gases Experiment
ALE	Atmospheric Lifetime Experiment
AmeriFlux	Eddy Covariance Flux Network in North, Central, and South America
AOML	Atlantic Ocean Marine Laboratory
BIOME-BGC	Biome model - biogeochemical cycle
BNL	Brookhaven National Laboratory
CARDS	Comprehensive Aerological Reference Data Set
CARINA	CARbon dioxide In the North Atlantic ocean
CDIAC	Carbon Dioxide Information Analysis Center
CFC	chlorofluorcarbon
CMDL	Climate Monitoring and Diagnostics Laboratory
CMP	computer model package
CO_2	carbon dioxide
CRU	Climate Research Unit
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTD	conductivity, temperature, and depth
DAAC	Distributed Active Archive Center
DB	database
DIST	Data and Information Sharing Tool
DMHB	*Data Management Handbook*
DLT	digital linear tape
DOE	U.S. Department of Energy
EC	eddy covariance
EPA	U.S. Environmental Protection Agency
ESD	Environmental Sciences Division
FACE	Free-Air CO_2 Enrichment
FAO	Food and Agriculture Organization
FGDC	Federal Geographic Data Committee
FLUXNET	Global collaboration of FLUX networks
FTP	File Transfer Protocol
FY	fiscal year
GAGE	Global Atmospheric Gases Experiment
GCDIS	Global Change Data and Information System
GIS	geographic information system
GLODAP	GLobal Ocean Data Analysis Project
GPP	gross primary production
GTS	Global Telecommunications System
HTML	Hypertext Markup Language
IPCC	Intergovernmental Panel on Climate Change
JGOFS	Joint Global Ocean Flux Study

JODC	Japan Oceanographic Data Center
LAI	leaf area index
MEDS	Marine Environmental Data Service (Canada)
MIT	Massachusetts Institute of Technology
MODIS	moderate-resolution imaging spectro-radiometer
MSU	microwave sounding unit
NARSTO	*formerly* North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautics and Space Administration
NEP	net ecosystem production
NDP	numeric data product
NIGEC	National Institute for Global Environmental Change
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPP	net primary production
NSF	National Science Foundation
NTSG	Numerical Terradynamic Simulation Group
OACES	Ocean-Atmosphere Carbon Exchange Study
ODBC	Open Database Connectivity
OME	ORNL Metadata Editor
OSU	Ohio State University
ORNL	Oak Ridge National Laboratory
pCO_2	partial pressure carbon dioxide
PDA	permanent data archive
PDF	portable document format
pH	pH value
Pg	petagram
PICES	North Pacific Marine Science Organization
PIs	principal investigators
PM	particulate matter
PMEL	Pacific Marine Environmental Laboratory
PNRA	Programma Nazionale di Recherche in Antartide
ppmv	parts per million by volume
pptv	parts per trillion by volume
QSSC	Quality Systems Science Center
QSMP	Quality Systems Management Plan
QPHB	Quality Planning Handbook
R^3	Request Response Record
RAID	redundant array of independent disk
RIHMI-WDC	Russian Research Institute for Hydrometeorological Information - World Data Center
R/V	Research Vessel
SAT	surface-air temperature
SF_5CF_3	trifluoromethyl sulphur pentafluoride
SF_6	sulphur hexafluoride

SIO	Scripps Institution of Oceanography
SOI	Southern Oscillation Index
SQL	Structured Query Language
SST	sea surface temperatures
TALK	total alkalinity
TCO_2	total carbon dioxide
TDE	Throughfall Displacement Experiment
Tg	teragram
UN	United Nations
UPS	uninterruptible power supply
WBW	Walker Branch Watershed
WDC	World Data Center
WG	Working Group
WHP	World Hydrographic Program
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWR	World Weather Records
XML	eXtensible Markup Language

10. References

1. Briffa, K. R., and P. D. Jones. 1993. Global surface air temperature variations during the twentieth century, Part 2, implications for large-scale high-frequency palaeoclimatic studies. *The Holocene* 377 - 88.

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