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A Vision for Climate Change Data Management

by Michael P. Farrell

Director's Note: CDIAC recently celebrated its twentieth anniversary as the U.S. Department of Energy's lead center for global-change data and information. We asked Michael Farrell, who was director of CDIAC during its first decade (and then head of Oak Ridge National Laboratory's Center for Global Environmental Studies), to look back on the changing role of data and information in support of global-change research, education, and decision making.

I would like to focus this short article on the future—the future of data management in the Climate Change Science Program (CCSP) (**http://www.climatescience.gov/**).

Let me start by saying that I believe a viable and responsive data management system is central to the success of the CCSP. In short, we can't get to where we want to be without it!

If I was king for a day, I would ask my colleagues in the data management community to:

- Develop a vision of data management for the CCSP that is for users and not for developers. Users set the requirements; computer pros put it into a working package. On the other hand, don't let computer nerds design the system—it will be access, access, and more access.

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What's Inside ...

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CDIAC's DOE Program Manager: Wanda Ferrell

Direct from the Director

I am pleased to note that CDIAC is now becoming involved with the management of data related to carbon sequestration. Sequestration, or storage, of carbon is a major component of the U.S. Department of Energy's strategy for addressing the issue of climate change (see **http://www.doe.gov/engine/content.do?BT_CODE=EN_SS3**). In addition to controlling emissions of carbon to the atmosphere (especially from the combustion of fossil-fuels, production of cement, and changes in land use and land cover), the United States and other countries are exploring techniques to sequester carbon in reservoirs for decades and longer. Considerable research and development (R&D) is aimed at potential carbon sinks in the terrestrial biosphere (i.e., vegetation and soil), the oceans, and geological repositories. Investigations also focus on techniques that might capture carbon directly from industrial processes for injection into marine or geological reservoirs.

Obviously, such R&D effort produces its own stream of data, which has to be properly managed – hence, the need for quality assurance, documentation, archival, and distribution. CDIAC is becoming involved to complement our other data and information related to global change and to better serve our diverse user community.

Our first steps in this direction, undertaken in collaboration with CSiTE [the DOE Consortium for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (**http://csite.esd.ornl.gov**)], have been in the area of terrestrial carbon sequestration. In this work, CDIAC has been assisted by Tris West and Lynn Kszos of ORNL's Environmental Sciences Division. If you turn to CDIAC's new Web site for carbon sequestration data (**http://cdiac.ornl.gov/programs/CSEQ/cseqprojectdata.html**), you'll find links to several key data sets contributed by researchers in the United Kingdom, Australia, and the United States. These data sets — focusing on conversion to and management of grassland, afforestation, tillage, and crop rotation — represent important syntheses of terrestrial carbon sequestration research. We are also working on other terrestrial data sets, which we expect to offer online in the near future. Beyond that, we hope to broaden our work to include data sets from other aspects of carbon sequestration, such as ocean carbon and geological carbon sequestration, CO_2 capture, and microorganism genome sequencing.

Bob Cushman

Director, Carbon Dioxide Information Analysis Center

(continued from page 1)

- Admit that data management for CCSP is not a technology challenge; the tools and know-how exist. The challenge is commitment to developing data management capability that (1) reflects the needs of the user community, (2) is created in a reasonable time-frame, and (3) is universally accepted as a value-added capability to the folks doing work (researchers, decision makers, policy makers, etc.).

- Design a data management system that is not a fixed, over-engineered, static system, outdated two years into the program. Change should be anticipated. The development of a data management system should be dynamic.

- Spell out what promises the data management research community is making to the CCSP over the next 5–10 years. We would understand why they are being made and what we need to change to make this happen, and we would jointly develop the metrics of success. Most importantly, we would get the buy-in from climate change researchers by promising something useful and available (in a prototype) very quickly.

- Recognize that (1) access to data is an important, but only part of the, problem faced by the research community, and perhaps the easiest part to solve; (2) interoperability is an important attribute of data management, but it should not be the critical goal of a CCSP data management system, perhaps not even in the top tier; and (3) standards and formats are important to many research areas (e.g., geographic data), but should not be the overarching goal of the CCSP data management efforts.

These shortcomings are fixable, and are being fixed—at least that is my hope. On a positive note, there is much we can do. I suggest two actions to get the ball rolling:

- Conduct a workshop on the "success" aspects (maybe failures, too) of the current climate-change data management experience. What has worked (or not worked)? Why has it worked (or not)? Figure out how to avoid the problems encountered in the past and incorporate past successes into the CCSP data management capability of the future.

- "Right-size" the CCSP data management budget. To do this you first have to develop a data management plan that is exciting and useful to users. A plan that will bring comments like, "Finally, a data management capability that works for me; helps me do my job and gain new insights into the data." Make data management a value-added enterprise of the CCSP, not an afterthought. Do this by holding data management accountable to the users. Promise and deliver new capabilities. Celebrate successes. Budgets and hearts will follow.

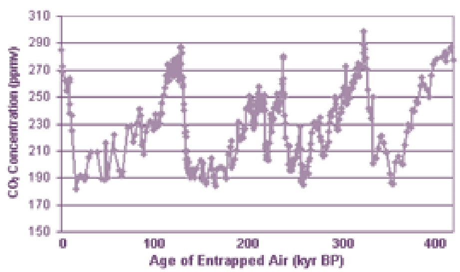
Mike

Additions & Updates

Atmospheric Trace Gas Concentrations

Atmospheric Carbon Dioxide

Historical CO_2 Record from the Vostok Ice Core
(J.-M. Barnola et al. 2003)
http://cdiac.ornl.gov/trends/co2/vostok.htm



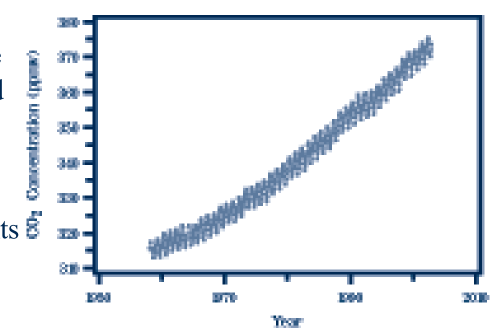
Source: Jean-Marc Barnola et al.

Updated Vostok data now extend the period of record by about 3000 years, so that the record spans from 417,160 to 2,342 years before present. In January 1998, the collaborative ice-drilling project between Russia, the United States, and France at the Russian Vostok station in East Antarctica yielded the deepest ice core ever recovered, reaching a depth of 3623 m. Ice cores are unique, with their long records of entrapped air, enabling direct measurement of past changes in atmospheric trace-gas composition. Preliminary data indicate the Vostok ice-core record extends through four climate cycles, with ice slightly older than 400 kyear (1 kyear = 1000 years). There is a close correlation between Antarctic temperature and atmospheric concentrations of CO_2. The extension of the Vostok CO_2 record shows that the main trends of CO_2 are similar for each glacial cycle. Major transitions from the lowest to the highest values are associated with glacial-interglacial transitions. During these transitions, the atmospheric concentrations of CO_2 rose from 180 parts per million by volume (ppmv) to 280–300 ppmv. At the beginning of deglaciations, the CO_2 increase was approximately in phase with Antarctic temperature, whereas it clearly lagged behind the temperature after the onset of deglaciation.

Atmospheric CO_2 Records from Sites in the SIO Air Sampling Network
(C. D. Keeling and T. P. Whorf 2003)
http://cdiac.ornl.gov/trends/co2/sio-keel.htm

Ambient atmospheric CO_2 data from the Mauna Loa Observatory, Hawaii; Barrow, Alaska; Cape Matatula, American Samoa; the South Pole, Antarctica; and Alert, Northwest Territories, Canada, have been updated with data through 2002.

The Mauna Loa atmospheric CO_2 measurements, which began in 1958, constitute the longest continuous record of atmospheric CO_2 concentrations 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 because 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 4-decade monitoring program.



Source: Dave Keeling and Tim Whorf (Scripps Institution of Oceanography)

The Mauna Loa record shows an 18% increase in the mean annual concentration, from 315.98 ppmv of dry air in 1959 to 372.95 ppmv in 2002. The increase in mean annual concentration from 2001 to 2002 was 2.06 ppmv (the largest single-year jump in the Mauna Loa record since recording began in 1958 was the 2.87 ppmv increase from 1997 to 1998).

Atmospheric CO_2 Record from Continuous Measurements at Jubany Station, Antarctica

(L. Ciattaglia et al. 2002)
http://cdiac.ornl.gov/trends/co2/jubany.htm

The Italian National Research Program in Antarctica has taken continuous atmospheric CO_2 measurements at Jubany Station, Antarctica, since March 1994. Jubany Station is situated on King George Island, in the South Shetland archipelago north of the Antarctic Penisula. Based on annual averages calculated from monthly averages running from March 1994 through December 2001, CO_2 levels at Jubany have risen from 356.75 ppmv in 1994 to 368.22 ppmv in 2001.

The general deceleration trend in the atmospheric CO_2 concentration first observed during 1997–1998 at Jubany and other Antarctic stations in the World Meteorological Organization's (WMO's) Global Atmospheric Watch network may have been caused by several factors, such as anomalies in sea surface and air temperatures and changes in general atmospheric circulation.

Atmospheric CO_2 Concentrations from the CSIRO GASLAB Flask Sampling Network

(L. P. Steele et al. 2003)
http://cdiac.ornl.gov/trends/co2/csiro/csiro_gaslab.html

Individual atmospheric CO_2 measurements were obtained from flask air samples for nine globally distributed stations [Alert, Northwest Territories, Canada; Cape Ferguson, Australia; Cape Grim, Australia; Estevan Point, British Columbia, Canada; Macquarie Island, Australia; Mauna Loa, Hawaii, U.S.A.; Mawson, Antarctica; Shetland Islands, Scotland; and South Pole, Antarctica] and returned to the CSIRO GASLAB for analysis. The period of record began as early as December 1990 for some stations and continued through December 2001. Average annual increases in CO_2 concentration since the early 1990s ranged from 1.5 ppmv/year to 1.8 ppmv/year.

Atmospheric Methane

Historic CH_4 Records from Antarctic and Greenland Ice Cores, Antarctic Firn Data, and Archived Air Samples from Cape Grim, Tasmania *(D. M. Etheridge et al. 2002)*

http://cdiac.ornl.gov/trends/atm_meth/lawdome_meth.html

A thousand-year record of atmospheric CH_4 concentrations was added to ***Trends Online***. CH_4 concentrations in air bubbles dating from 1008 to 1980 in Antarctic ice cores, and from 1075 to 1885 in Greenland ice cores indicate "pre-industrial" (before 1750) concentrations of 722 ppb in high Northern-Hemisphere latitudes and 680 ppb in high Southern Hemisphere latitudes. Present-day concentrations are 1842 ppb at Mace Head Ireland, and 1729 ppb at Cape Grim, Tasmania. This database also contains records of air in firn samples dated roughly from 1978 to 1993; these data compare well with CH_4 concentrations in archived air samples from Cape Grim for the years 1978–1995.

Atmospheric CH_4 Concentrations from the CSIRO GASLAB Flask Sampling Network

(L. P. Steele et al. 2003)
http://cdiac.ornl.gov/trends/atm_meth/csiro/csiro_gaslabch4.html

Individual atmospheric CH_4 concentrations were obtained from flask air samples for nine globally distributed sites (Alert, Northwest Territories, Canada; Cape Ferguson, Australia; Cape Grim, Australia; Estevan Point, British Columbia, Canada; Macquarie Island, Australia; Mauna Loa, Hawaii, U.S.A.; Mawson, Antarctica; Shetland Islands, Scotland; and the South Pole, Antarctica) and returned to the CSIRO GASLAB for analysis. Typical sample storage times ranged from days to weeks for some sites (e.g., Cape Grim) and to as much as one year for Macquarie Island and the Antarctic sites. Experiments were carried out to test for any change in sample CH_4 mixing ratio.

Atmospheric Carbon Monoxide

Atmospheric CO Concentrations from the CSIRO GASLAB Flask Sampling Network

(L. P. Steele et al. 2003)
http://cdiac.ornl.gov/trends/otheratg/csiro-co/csiro_gaslabco.html

Individual CO measurements were obtained from flask air samples for nine globally distributed sites (Alert, Northwest Territories, Canada; Cape Ferguson, Australia; Cape Grim, Australia; Estevan Point, British Columbia, Canada; Macquarie Island, Australia, Mauna Loa, Hawaii, U.S.A.; Mawson, Antarctica; Shetland Islands, Scotland; and the South Pole, Antarctica) and returned to the CSIRO GASLAB for analysis. The period of record began as early as May 1984 for some stations and continued through December 2001. Long-term trends were not evident in these data. However, peak concentrations were observed on a global scale in 1998; these may be related to unusually large amounts of biomass burning in southeast Asia, especially Indonesia, and also in South America.

Atmospheric Hydrogen

Atmospheric H_2 Concentrations from the CSIRO GASLAB Flask Sampling Network

(L. P. Steele et al. 2003)
http://cdiac.ornl.gov/trends/otheratg/csiro-h2/csiro_gaslabh2.html

Individual atmospheric H_2 measurements were obtained from flask air samples for nine globally distributed stations (Alert, Northwest Territories, Canada; Cape Ferguson, Australia; Cape Grim, Australia; Estevan Point, British Columbia, Canada; Macquarie Island, Australia; Mauna Loa, Hawaii, U.S.A.; Mawson, Antarctica; Shetland Islands, Scotland; and the South Pole, Antarctica) and returned to the CSIRO GASLAB for analysis. The period of record for most stations began in 1992 and continued through December 2001. Long-term trends were not evident in these data. However, globally averaged peak concentrations were observed on a global scale in 1998. Tuhese may be related to unusually large amounts of biomass burning in southeast Asia, especially in Indonesia and also in South America.

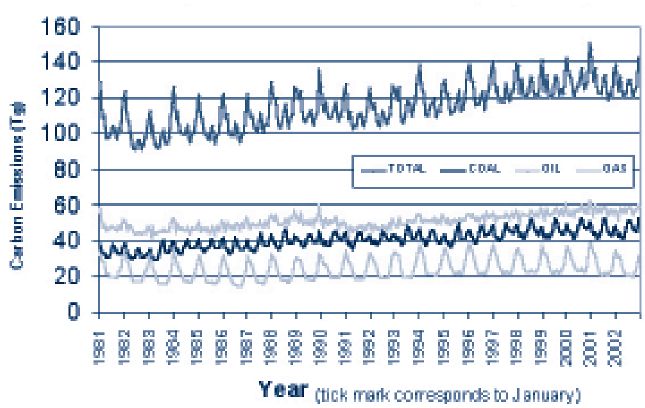
Greenhouse Gas Emissions

Carbon Dioxide Emissions

Estimates of Monthly CO_2 Emissions and Associated $^{13}C/^{12}C$ Values from Fossil-Fuel Consumption in the U.S.A.

(T. J. Blasing et al. 2003)
http://cdiac.ornl.gov/trends/emis_mon/emis_mon_co2.html

Estimates of monthly CO_2 emissions and associated $^{13}C/^{12}C$ values from fossil-fuel consumption in the U.S. are available for the years 1981–2002. These estimates were derived from values of fuel consumed, multiplied by their respective thermal conversion factors, and then multiplied by their respective CO_2 emission factors. An annual cycle, peaking during the winter months and reflecting natural gas consumption, and a semi-annual cycle of lesser amplitude, peaking in summer and winter and reflecting coal consumption, comprise the dominant features of the annual pattern. There were relatively constant emissions until 1987, followed by an increase during 1987–1989, a decrease in 1990–1991, and record highs during the late 1990s; emissions have declined somewhat since 2000.

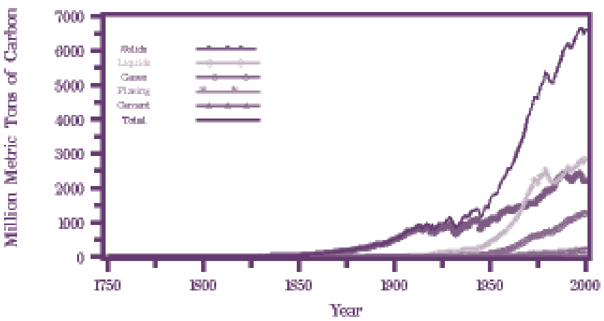


Global, Regional, and National Fossil Fuel CO_2 Emissions

(G. Marland et al. 2003)

http://cdiac.ornl.gov/trends/emis/em_cont.htm

Estimates of CO_2 emissions from fossil-fuel combustion and cement production, on global, regional, and national scales, are available for 1751–2000. The estimate for 2000 global CO_2



emissions, 6611 million metric tons of carbon, represents a 1.8% increase from 1999. These estimates, derived primarily from energy statistics published by the United Nations (U.N.), were calculated by 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 U.N. data but were supplemented with data from R. Rotty, and with a few national estimates provided by Marland.

Carbon Flux from Land-Cover Change

Carbon Flux to the Atmosphere from Land-Use Changes

(R. A. Houghton and J. L. Hackler 2002)

http://cdiac.ornl.gov/trends/landuse/houghton/houghton.html

Estimates of carbon flux to the atmosphere from land-use changes have been updated with estimates extending from 1850 through 2000. This database provides annual estimates of net fluxes caused by deliberate changes in land use (e.g., clearing of forests for agriculture, harvest of wood for fuel or timber) in nine regions of the world. The estimated global total net flux of carbon from changes in land use increased from 0.5 Pg C (1 petagram = 10^{15} or 1,000,000,000,000,000 grams) in 1850 to a maximum of 2.4 Pg C in 1991 and then declined to 2.1 Pg C in 2000. The global net flux during the period 1850–2000 was 156 Pg C, about 63% of which was from the tropics. During this period, the greatest regional flux was from Tropical Asia (48 Pg C), while the smallest regional flux was from North Africa and the Middle East (3 Pg C). The global total flux averaged 2.0 Pg C/year during the 1980s and 2.2 Pg C/year during the 1990s (but generally declining during that latter decade), dominated by fluxes from tropical deforestation. For the United States, the estimated flux is a net source of 7 Pg C to the atmosphere for the period 1850–2000, but a net sink of 1.2 Pg C for the 1980s and 1.1 Pg C for the 1990s.

Climate

Temperature

Global, Hemispheric, and Zonal Temperature Deviations Derived from Radiosonde Records

(J. K. Angell 2003)

http://cdiac.ornl.gov/trends/temp/angell/angell.html

CDIAC has updated the "Global, Hemispheric, and Zonal Temperature Deviations Derived from Radiosonde Records" (**http://cdiac.esd.ornl.gov/trends/temp/angell/angell.html**) and updated the corresponding numeric data package "Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958–2002" (NDP-008, **http://cdiac.esd.ornl.gov/ndps/ndp008.html**). Data from a global network of 63 radiosonde stations were used to estimate temperature deviations from 1958 through 2002. These estimates are categorized vertically (for the near-surface, troposphere, tropopause, low stratosphere, and the near-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 1958–2002 the global mean near-surface air temperature warmed by 0.16° C/decade and the 850–300 mb troposphere layer warmed by 0.08° C/decade. The global mean 300–100 mb tropopause layer cooled by approximately -0.20° C/decade, driven mainly by large changes in the polar zones, and the 100–50 mb low-stratospheric layer experienced a global mean cooling of about -0.60° C/decade.

Ecosystems

Area and Carbon Content

Area and Carbon Content of *Sphagnum* Since Last Glacial Maximum

(K. Gajewski et al. 2002)
http://cdiac.ornl.gov/trends/ecosystems/gajewski2.html

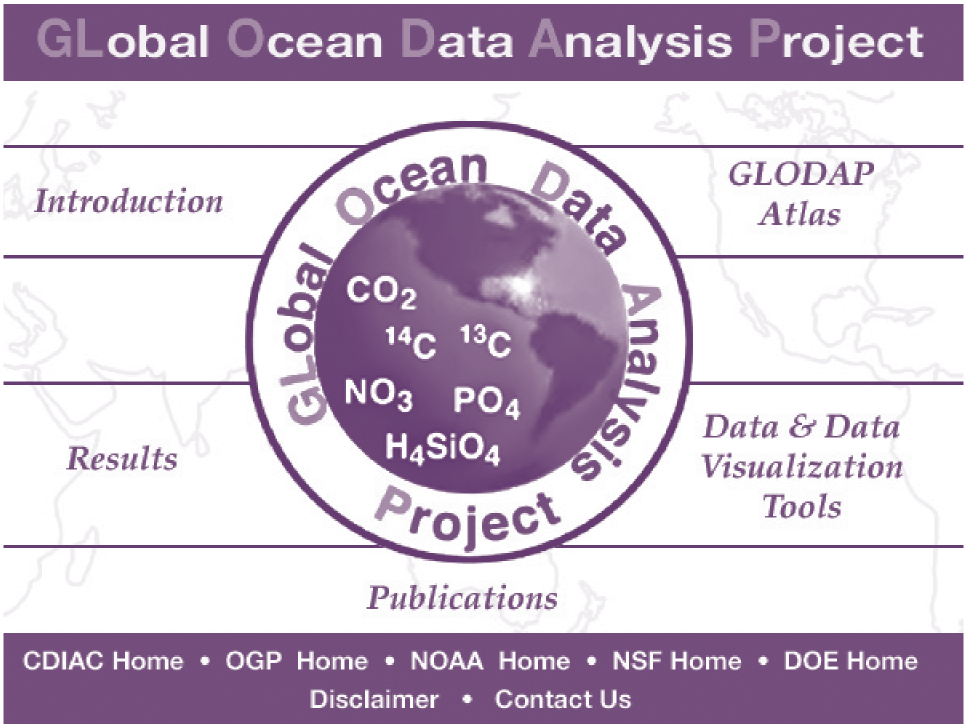
The first in a new ***Trends Online*** "Ecosystems" section, this database estimates area (estimated separately for North America, Europe, and Asia) and total carbon content (low, high, and mean values) at 2000-year intervals on the basis of the distribution and abundance of *Sphagnum* spores in North America and Eurasia over the past 21 kyears (i.e., 21,000 years). Carbon accumulation in peatlands is estimated to be low prior to 11 kyear BP (before present), increased slightly between 11 and 5 kyears BP, and greatly increased during the past 5 kyears BP.

Focus Area Outreach

CDIAC's archive of data for the Free-Air CO_2 Enrichment (FACE) program now includes data from the FACTS II FACE research site in Rhinelander, Wisconsin (**http://cdiac.ornl.gov/programs/FACE/facts-IIdata/factsIIdata.html**). FACTS II is a multidisciplinary study to assess the effects of increasing tropospheric ozone and CO_2 levels on aspen forest ecosystems. The first data set from the Rhinelander, Wisconsin, site was contributed by Jaak Sober, Wendy Jones, and David Karnosky (Michigan Technological University), and it quantifies the measured atmospheric concentrations of CO_2 in control and enriched (target concentration = ambient + 200 ppm) rings.

Data from the FACE research site in Bulls, New Zealand (**http://cdiac.ornl.gov/programs/FACE/nzdata/nzdata.html**) comprises the first data set from the New Zealand pasture site. This database was contributed by Paul Newton and Harry Clark (Agresearch, Palmerston North, New Zealand), and it quantifies the effects of CO_2 enrichment [ambient (360 ppm) versus elevated (475 ppm)] and management (grazed versus ungrazed) on plant dry weight.

ORNL's FACE research site (**http://cdiac.esd.ornl.gov/programs/FACE/ornldata/ornldata.html**) has been expanded to include 1999–2002 data on the leaf area index (LAI) measured at the FACE rings. These data were contributed by the ORNL Environmental Sciences Division's Richard Norby, Johnna Sholtis (Texas Tech University), Carla Gunderson, and Sara Jawdy (to accompany their forthcoming paper "Leaf Dynamics of a Deciduous Forest Canopy: No Response to Elevated CO_2" in the journal *Oecologia*). Previously archived ORNL FACE data include measured CO_2 concentrations, wind speed and direction, and solar angle. Future data sets will cover tree basal area and other response variables.



A new Web site has been developed at CDIAC for the Global Ocean Data Analysis Project (GLODAP) (**http://cdiac.ornl.gov/oceans/glodap/Glodap_home.htm**). The site includes a North Pacific database for ocean CO_2 and related parameters, written documentation of best practices for ocean CO_2 measurements, and coordination of future North Pacific measurement programs.

CDIAC has also opened a Live Access Server for the ocean carbon data from the GLODAP Web site. To access the server, click on "Data & Data Visualization Tools" and "Live Access Server (LAS) for GLODAP Gridded and Bottle Data".

CDIAC's Pacific and Indian Ocean carbon-related data collections have been formatted for users of the Ocean Data View (ODV) software. ODV is a multi-platform software package for the interactive exploration and visualization of oceanographic data and was written by R. Schlitzer of the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany. The Pacific Ocean ODV collection (**http://cdiac.ornl.gov/oceans/pacific_ODV.html**) consists of data from 3,034 stations in 27 WOCE sections. The Indian Ocean ODV collection (**http://cdiac.ornl.gov/oceans/indian_ODV.html**) consists of data from 1,395 stations in 13 WOCE sections. Users can follow instructions on the Web page to download the ODV program from the ODV software Web site.

CDIAC's Atlantic Ocean carbon-related data collections have also been formatted for users of ODV software. The Atlantic Ocean ODV collection (**http://cdiac.ornl.gov/oceans/atlantic_ODV.html**) consists of data from 2,293 stations in 22 WOCE sections. The Atlantic Ocean ODV data collection joins the previously announced collections for the Pacific and Indian oceans (**http://cdiac.ornl.gov/oceans/datameta.html**).

NARSTO

The following is a list of data sets from the EPA Particulate Matter Supersites Research Program that have been archived in the NARSTO Permanent Data Archive (**http://eosweb.larc.nasa.gov/project/narsto/table_narsto.html**) at the NASA Langley Research Center DAAC.

• Pittsburgh's "Rapid Single-Particle Mass Spectrometer Data"

• Los Angeles's "TEOM PM2.5 Mass Concentration Data"

• Houston's "Differential Mobility Analyzer Data"

• Atlanta's "Rapid Single-Particle Mass Spectrometer Data"

• Los Angeles's "TEOM PM2.5 Mass Concentration Data"

• Houston's "Washburn Tunnel Air Quality Monitoring Data"

• Los Angeles's "Scanning Mobility Particle Size Data"

Carbon Sequestration

CDIAC has released data summarizing the effects of crop rotation and tillage practices on soil carbon sequestration rates (**http://cdiac.ornl.gov/programs/CSEQ/terrestrial/westpost2002/westpost2002.html**). These data, provided by Tris West and Mac Post (DOE Center for Research on Carbon Sequestration in Terrestrial Ecosystems and ORNL Environmental Sciences Division), are from a paper that will soon appear in the *Soil Science Society of America Journal*.

Several additional databases related to terrestrial carbon sequestration are available online (**http://cdiac.ornl.gov/programs/CSEQ/cseqprojectdata.html**). These include: "Potential for Carbon Sequestration in European Soils: Preliminary Estimates for Five Scenarios Using Results from Long-Term Experiments" and "Preliminary Estimates of the Potential for Carbon Mitigation in European Soils Through No-Till Farming" both of which were contributed by P. Smith, D. Powlson, M. Glendining, and J. Smith (University of Aberdeen); "Grassland Management and Conversion into Grassland: Effects on Soil Carbon," contributed by R. Conant, K. Paustian, and E. Elliot (Colorado State University); and "Changes in Soil Carbon Following Afforestation," contributed by K. Paul, P. Polglase, G. Nyakuengama, and P. Khanna (Commonwealth Scientific and Industrial Research Organisation, Australia).

Ecosystems

CDIAC has posted on the Web the results from an intercomparison of ecosystem models that were run with data from the Throughfall Displacement Experiment (TDE) at ORNL (**http://cdiac.esd.ornl.gov/epubs/tdemodel/tdemodel.html**). The model intercomparison project was coordinated by P. Hanson of the ORNL Environmental Sciences Division and involved modelers from a number of institutions (J. Amthor, A. King, and S. Wullschleger, ORNL Environmental Sciences Division; R. Grant, University of Alberta, Canada; A. Hartley, The Ohio State University; D. Hui, University of Oklahoma; R. Hunt and S. McNulty, U.S. Department of Agriculture; D. Johnson, University of Nevada, Reno; J. Kimball and P. Thornton, University of Montana; Y. Luo, University of Oklahoma; Ge Sun, North Carolina State University; S. Wang, Natural Resources Canada; M. Williams, University of Edinburgh, United Kingdom; and K. Wilson, U.S. Department of Commerce). The project compares model estimates of evapotranspiration, net ecosystem carbon exchange, production, respiration, and growth.

New and Updated Databases

CDIAC's data holdings cover a number of areas relevant to the greenhouse effect and global climate change. Such areas include records of the concentration of 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 to the atmosphere; long-term climate trends; the effects of elevated CO_2 on vegetation; and the vulnerability of coastal areas to rising sea level. Data distributed by CDIAC are released as numeric data packages (NDPs), computer model packages (CMPs), and databases. Recently released data are described in this section. The data and documentation (text or HTML version) may be accessed and downloaded from CDIAC's Web site (**http://cdiac.ornl.gov/**), from CDIAC's anonymous FTP area (**cdiac.ornl.gov**) or requested directly from CDIAC on a variety of media (e.g., CD-ROM, floppy diskette). Technical questions (e.g., methodology or accuracy) should be directed to the CDIAC staff member who is responsible for preparing the individual NDP.

Carbon Dioxide, Hydrographic and Chemical Data Obtained During the Knorr Cruises Comprising the Indian Ocean CO_2 Survey (WOCE Sections I8Si9S, I9N, I8NI5E, I3, I5WI4, I7N, I1, I10, and I2; December 1, 1994–January 22, 1996)

http://cdiac.ornl.gov/oceans/ndp_080/ndp080.html
K. M. Johnson et al. 2002. ORNL/CDIAC-138, NDP-080
Prepared by Alex Kozyr, CDIAC

This database supports studies of the transport of CO_2 within the Indian Ocean and movement of CO_2 between the ocean and atmosphere. Measurements made during this WOCE cruise included total CO_2 and total alkalinity, along with hydrographic and nutrient data. Unlike other CO_2 survey cruises where a single institution was responsible for all phases of the work, these cruises were a group effort in which the measurement groups used the same ship and instrumentation for a 14-month period. The first cruise began in Freemantle, Australia, on December 1, 1994, and the final cruise ended in Mombasa, Kenya, on January 22, 1996.

Cloud Climatology for Land Stations Worldwide, 1971–1996

http://cdiac.ornl.gov/epubs/ndp/ndp026d/ndp026d.html
C. J. Hahn and S. G. Warren. 2002. ORNL/CDIAC-142, NDP-026D
Prepared by Dale Kaiser, CDIAC

Surface synoptic weather reports for 26 years were processed to provide a climatology of clouds for more than 5000 land-based weather stations with long periods of record both day and night. For each station, this digital archive includes multi-year annual, seasonal, and monthly averages for day and night separately; seasonal and monthly averages by year; averages for eight times per day; and analyses of the first harmonic for the annual and diurnal cycles. Averages are given for total cloud cover, clear-sky frequency, and nine cloud types: five in the low level (fog, St, Sc, Cu, Cb), three in the middle level (Ns, As, Ac), and one in the high level (all cirriform clouds combined). Cloud amounts and frequencies of occurrence are given for all types. In addition, non-overlapped amounts are given for middle and high cloud types, and average base heights are given for low cloud types. Nighttime averages were obtained by using only those reports that met an "illuminance criterion" (i.e., made under adequate moonlight or twilight), thus making possible the determination of diurnal cycles and nightime trends for cloud types.

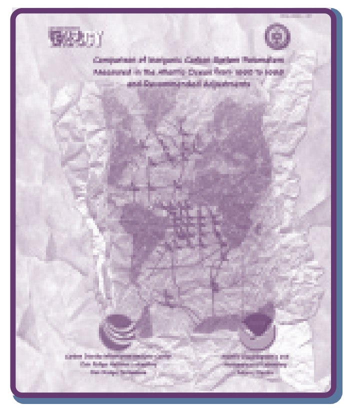
Global, Regional, and National Annual CO_2 Emissions from Fossil-Fuel Burning, Cement Production, and Gas Flaring: 1751–2000

http://cdiac.ornl.gov/ndps/ndp030.html
G. Marland et al. 2003. NDP-030
Prepared by Tom Boden, CDIAC

Global, regional, and national annual estimates of CO_2 emissions from fossil fuel burning, cement production, and gas flaring have been calculated through 2000, some as far back as 1751. These estimates, derived primarily from energy statistics published by the U.N., were calculated by 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 U.N. data but were supplemented with data from the U.S. Department of Energy's Energy Information Administration, and with a few national estimates provided by Marland.

Comparison of Inorganic Carbon System Parameters Measured in the Atlantic Ocean from 1990 to 1998 and Recommended Adjustments

http://cdiac.ornl.gov/oceans/aoml/cdiac_140.html
R. Wannikov et al. 2003. ORNL/CDIAC-140
Prepared by Alex Kozyr, CDIAC



Researchers performed a comprehensive comparison of inorganic carbon parameters that were measured in oceanographic surveys conducted under the auspices of the Joint Global Ocean Flux Study and related programs. Many of the cruises were part of the World Hydrographic Program of WOCE and the NOAA Ocean-Atmosphere Carbon Exchange Study. Total dissolved inorganic carbon (DIC), total alkalinity (TAlk), fugacity of CO_2, and pH data from 23 cruises were checked to determine whether there were systematic offsets of these parameters between cruises. The focus was on the DIC and TAlk state variables. Data quality and offsets of DIC and TAlk were determined by using several different techniques. For several of the cruises, small adjustments in TAlk were recommended for consistency with other cruises in the region. After these adjustments were incorporated, the inorganic carbon data from all cruises along with hydrographic, chlorofluorocarbon, and nutrient data were combined as a research-quality product for the scientific community.

The ALE/GAGE/AGAGE Network

http://cdiac.ornl.gov/ndps/alegage.html
R. Prinn et al. 2003. DB1001
Prepared by T. J. Blasing, CDIAC

The global ALE/GAGE/AGAGE monitoring network was updated with data through September 2002 for five sites: Cape Grim, Tasmania; Point Matatula, American Samoa; Ragged Point, Barbados; Mace Head, Ireland; and Trinidad Head, California (stations also previously existed at Cape Meares, Oregon, and Adrigole, Ireland). This database provides continuous high-frequency measurements of CH_4, N_2O, several halogenated hydrocarbons, CO, and H_2, and it supports analyses and monitoring related to greenhouse gases and to the Earth's ozone layer.

CSIRO GASLAB Network: Individual Flask Measurements of Atmospheric Trace Gases

http://cdiac.ornl.gov/epubs/db/db1021/db1021.html

L. P. Steele et al. 2003. DB1021

Prepared by T. J. Blasing, CDIAC

This database contains data for four atmospheric trace gases collected at nine stationary sites and one moving platform (aircraft over Cape Grim, Tasmania, and at Bass Strait, between the Australian continent and Tasmania). The trace gases are CO_2, CH_4, CO, and H_2. The nine stationary sites are, from north to south: Alert, Canada; Shetland Islands, Scotland; Estevan Point, Canada; Mauna Loa, Hawaii, U.S.A.; Cape Ferguson, Australia; Cape Grim, Australia; Macquarie Island, Australia; Mawson, Antarctica; and the South Pole, Antarctica. The earliest data are from April 1984 (period of record varies by gas and station). The data extend through September 2000 for aircraft data and through December 2001 for the stationary sites.

Measurements of the ^{13}C isotopic fraction of CO_2 were also sampled at these nine stations. The period of record for the ^{13}C isotopic fraction of CO_2 began during 1990 at all but two stations: Estevan Point and the Shetland Islands. These data are current through 2001 except for the South Pole station because analysis for the South Pole takes longer than for the less remote sites. The downward trend in ^{13}C isotopic fraction, reflecting the increase in fossil-fuel derived CO_2 in the atmosphere, is evident at all stations.

δ ^{13}C in CH_4 and CO, and Deuterium in CH_4, in Atmospheric Samples from Niwot Ridge, Colorado, and Montaña de Oro, California, United States

http://cdiac.ornl.gov/epubs/db/db1022/db1022.html

S. C. Tyler. 2003. DB1022

Prepared by T. J. Blasing, CDIAC

This database contains measurements of atmospheric CH_4 concentrations and associated D (deuterium, a hydrogen isotope), CO mixing ratio, and $^{13}C/^{12}C$ isotope ratio in atmospheric CO collected at approximately bi-weekly intervals from two fixed surface sites in the U.S.A., Niwot Ridge, Colorado, a mid-contential site, and Montaña de Oro, California, a Pacific Coast site receiving strong westerlies.

The continuous record of CH_4 mixing ratio and ^{13}C-CH_4 from Niwot Ridge extends from 1995 to 1998, while that of Montaña de Oro extends from 1996 to 1998. This time series can provide information relating seasonal cycling of CH_4 sources and sinks in background air, a record of long-term trends in CH_4 mixing and isotope ratio related to the atmospheric CH_4 loading, and possibly, an indication of regional CH_4 sources.

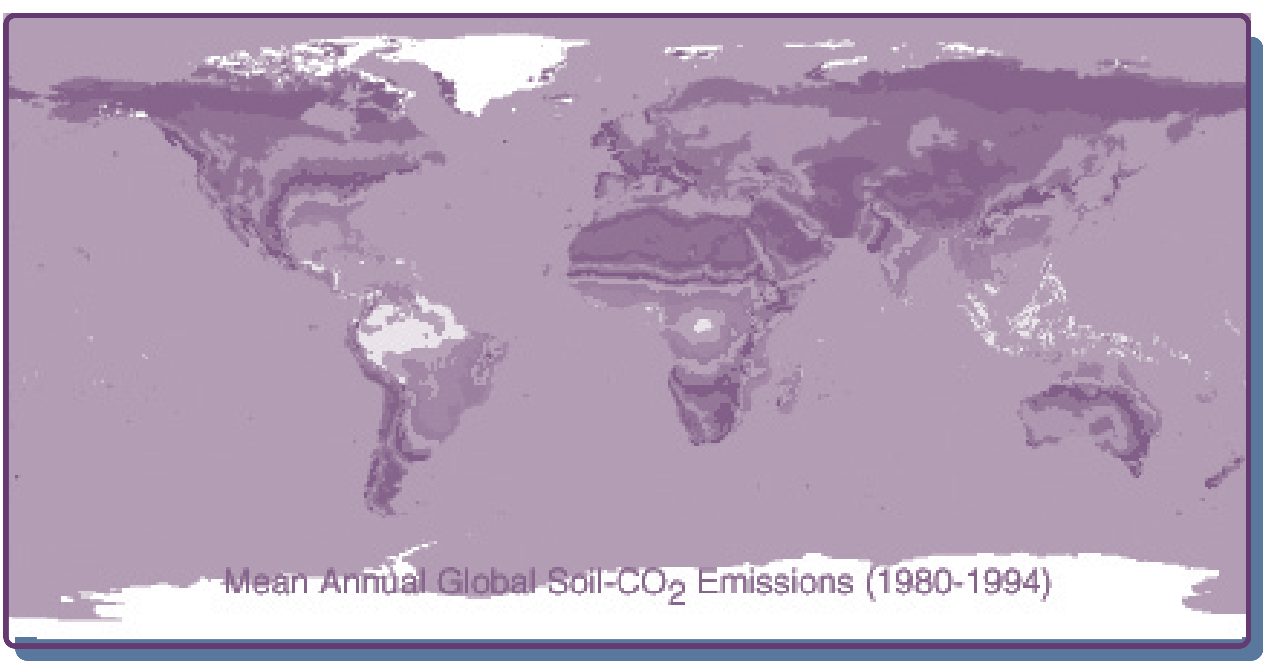
The continuous measurements of CO mixing ratio for Niwot Ridge extends back to 1995, while that for Montaña de Oro extends back to 1996. Measurements of $^{13}C/^{12}C$ isotope ratio in atmospheric CO were begun at both stations during 2000. Data for CH_4 and CO, and associated stable carbon and hydrogen isotopes, are available for Niwot Ridge through April 2001 and for Montaña de Oro through December 2001.

Interannual Variability in Global Soil Respiration on a 0.5 Degree Grid Cell Basis (1980–1994)
http://cdiac.ornl.gov/epubs/ndp/ndp081/ndp081.html
J. W. Raich et al. 2003. NDP-081
Prepared by Lisa Olsen, CDIAC

A climate-driven regression model was used to develop spatially resolved estimates of soil-CO_2 emissions from the terrestrial land surface for each month from January 1980 to December 1994 in order to evaluate the effects of interannual variations in climate on global soil-to-atmosphere CO_2 fluxes. The mean annual global soil-CO_2 flux over this 15-year period was estimated to be 80.4 (range 79.3–81.8) Pg C. Monthly variations in global soil-CO_2 emissions followed closely the mean temperature cycle of the Northern Hemisphere. Globally, soil-CO_2 emissions reached their minima in February and peaked in July and August. Tropical and subtropical evergreen broad-leaved forests contributed more soil-derived CO_2 to the atmosphere than did any other vegetation type (~30% of the total) and exhibited a biannual cycle in their emissions. Soil-CO_2 emissions in other biomes exhibited a single annual cycle that paralleled the seasonal temperature cycle.

Interannual variability in estimated global soil-CO_2 production is substantially less than the variability in net carbon uptake by plants (i.e., net primary productivity). Thus, soils appear to buffer atmospheric CO_2 concentrations against far more dramatic seasonal and interannual differences in plant growth. Within seasonally dry biomes (savannas, bushlands, and deserts), interannual variability in soil-CO_2 emmissions correlated significantly with interannual differences in precipitation.

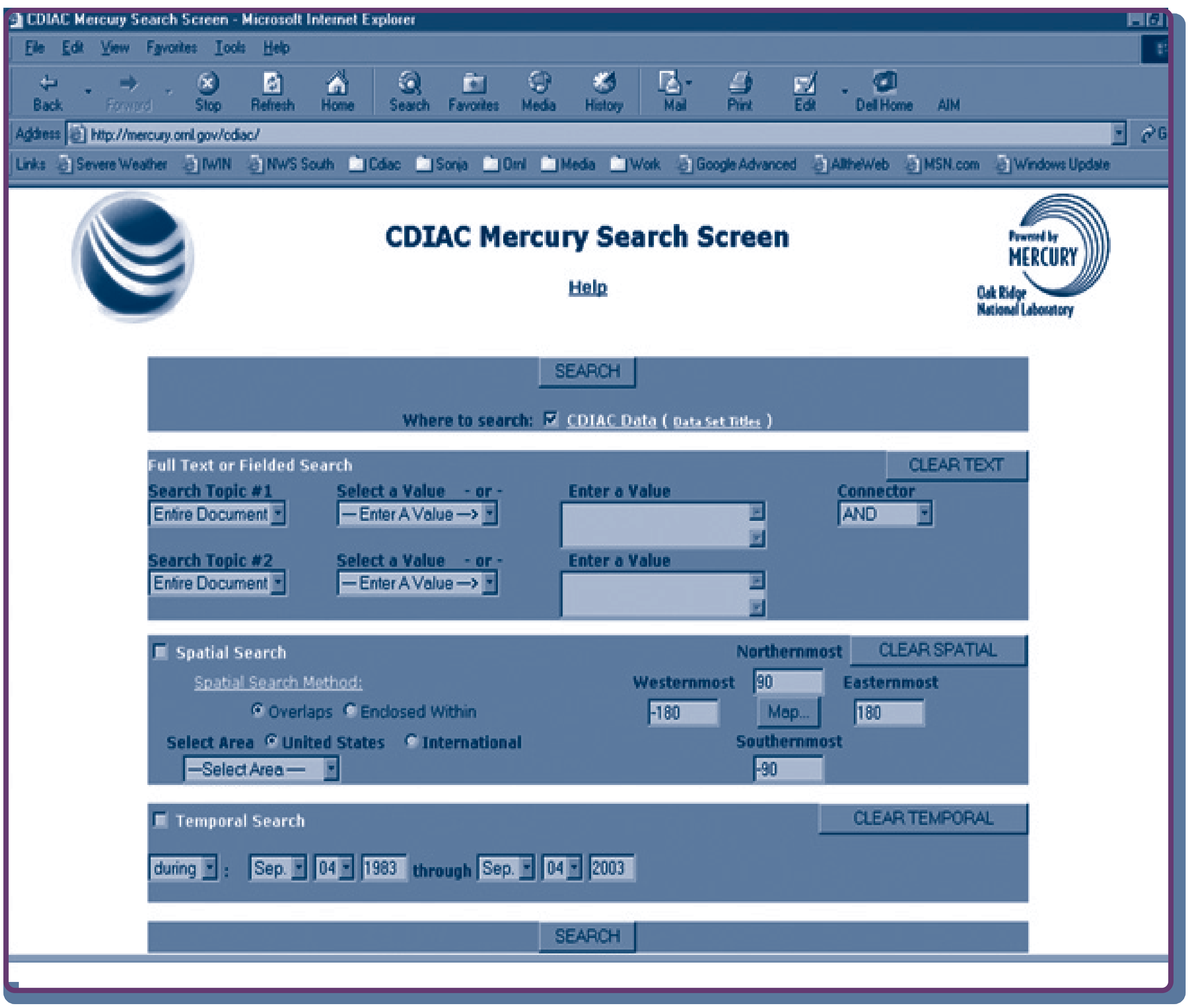
At the global scale, however, annual soil-CO_2 fluxes correlated with mean annual temperature, with a slope of 3.3 Pg C/year per degree Celsius. Although the distribution of precipitation influences seasonal and spatial patterns of soil-CO_2 emissions, global warming is likely to stimulate CO_2 emissions from soils.



New CDIAC Mercury Search Feature

CDIAC has launched a new search engine for locating CDIAC data and information products. To access the search tool, click on the "Search" button on the CDIAC home page (**http://cdiac.ornl.gov/**). This feature, which uses ORNL's Mercury software, allows users to conduct fielded searches (i.e., to search by product number, title, author, subject area, keyword) or to search the entire metadata record for the products. The tool also lets users search by the geographic location or the period of record of the data. Search results are summarized on a Web page listing the relevant database. By clicking on the database name, users can access short descriptions of the products and ultimately access the data and information products themselves. The CDIAC Mercury search feature, underlying metadata format, and editing tools, were developed by Chris Lindsley and Stan Attenberger of the ORNL Computational Sciences & Engineering Division, along with Tommy Nelson of CDIAC.

Users are still welcome to locate CDIAC data and information from the traditional "Products" page, which is also a click away from the CDIAC home page.



CDIAC Publications

Publications, Presentations, and Awards

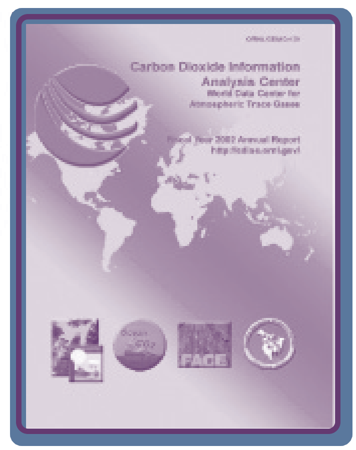
http://cdiac.ornl.gov/epubs/cdiac/cdiac101/pubslist.html
Robert M. Cushman. 2003. ORNL/CDIAC-101
Prepared by Bob Cushman, CDIAC

This online publication lists journal articles, books, proceedings chapters, numeric data packages, online databases, and other ORNL and DOE reports published by CDIAC; presentations of CDIAC staff; and awards presented to CDIAC since its inception in 1982.

Carbon Dioxide Information Analysis Center and World Data Center for Atmospheric Trace Gases Fiscal Year 2002 Annual Report

http://cdiac.ornl.gov/epubs/cdiac/cdiac139/2002annrpt.html **(coming soon)**
http://cdiac.ornl.gov/epubs/cdiac/cdiac139/2002annrpt.pdf
Robert M. Cushman et al. 2003. ORNL/CDIAC-139
Prepared by Carolyn Householder, CDIAC

The fiscal year 2002 annual report reviews the previous year's accomplishments, recalling new and updated data and information products, information of relevance to CDIAC Focus Areas (e.g., AmeriFlux, NARSTO, FACE, Oceans), staff presentations and awards, CDIAC citations, and statistics on requests for CDIAC information. The report lists publications and databases CDIAC will be working on in the coming fiscal year, plus collaborating institutions, a staff listing, and an acronym and abbreviation list.



Graduate Student Theses Supported by DOE's Environmental Sciences Division: Fiscal Year 2001 Update

http://cdiac.ornl.gov/epubs/cdiac/cdiac136/cdiac136.html
Robert M. Cushman. 2002. ORNL/CDIAC-136
Prepared by Bob Cushman, CDIAC

This document updates the 1995, 2000, and 2001 Graduate Student Theses reports, providing complete bibliographic citations, abstracts, and keywords for doctoral and master's degree theses published in late 2001 and 2002.

Vast Deep Web Resources Unlocked

Looking for obscure yet important science and technology information? The U.S. Department of Energy's Office of Scientific and Technical Information (OSTI) **(http://www.osti.gov)** has launched a series of ground breaking, Web searching products, making a vast array of deep stuff available. A great deal of non-DOE material is also included.

As OSTI director Walt Warnick explains, "the library includes three vast virtual resources for web patrons, covering each of the three main ways by which scientists and engineers communicate their findings: gray literature, preprints, and journal literature. Many other resources of interest are also available, including the new DOE R&D portfolio web site."

Gray literature, which includes technical reports produced by DOE national laboratories and grantees, is presented in the OSTI Information Bridge **(http://www.osti.gov/bridge/)**. It has over 85,000 searchable reports comprising millions of pages. In addition, the GrayLIT Network provides a portal to over 119,000 full-text technical reports from various other Federal agencies.

Servers around the world host preprints and ePrints, the newest way by which scientists communicate their findings. The OSTI E-print Network **(http://www.osti.gov/eprints)** links to many of these preprint servers, with an estimated 400,000 e-prints, and makes them accessible via a variety of indexing techniques. Especially innovative is the distributed search feature, which allows patrons to launch parallel searches on any or all of the preprint servers that have their own search engines.

Peer-reviewed journal literature is presented by a variety of tools presenting bibliographic information about articles in disciplines relevant to the DOE R&D program. OSTI and the Government Printing Office, via a new Interagency Agreement, provide the Energy Citations Database (ECD) **(http://www.osti.gov/energycitations/)**. ECD provides public access to bibliographic citations of scientific publications of DOE and predecessor agencies' scientific and technical information from 1948 to the present, with links to electronic full text when available. Full-text documents in this system are available in Depository Libraries and online via GPO Access.

There is also the DOE R&D Accomplishments Web site **http://www.osti.gov/accomplishments)**, and the DOE R&D Project Summaries, which describes approximately 22,000 recent or ongoing research and development projects. Likewise, Federal Research and Development Project Summaries provides Federal R&D information from over 370,000 project summaries.

Beyond all this, OSTI provides the technical support for the new interagency web site (**http://www.science.gov**). The ten principal federal science and technology agencies have launched this ambitious web portal to make their nonmilitary, government-funded research results available to all.

Despite its "Science" name, the site also provides access to vast amounts of technology development results, including the Patent Server on the web site of the U.S. Patent and Trademark Office. Science.gov does not include all of the research repositories of all the agencies, but just what its creators term the "best and brightest content."

Contributed by David E. Wojick, freelance journalist under contract to OSTI.

CDIAC Bookshelf

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Climate Change: Causes, Effects, and Solutions
Author: John T. Hardy. 2003. John Wiley & Sons Ltd.
http://www.wiley.com/

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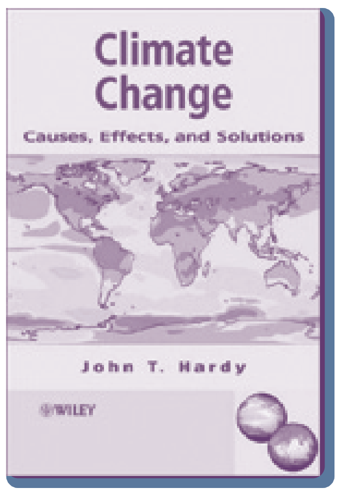
The book, *Climate Change: Causes, Effects, and Solutions,* focuses not only on the science issues related to climate change, but also on the policy issues involved. The book offers a clear description of the causes of climate change and documents the current and future effects of climate change on ecosystems, agriculture, sea level, human health, and infrastructure. Case studies from North America, Europe, Australasia, and elsewhere are presented, and proposed actions to reduce climate change or its impacts at the individual, national, and international levels are discussed.



While modern industrialized economies depend largely on the combustion of coal, oil, and gas, this burning of fossil fuels is increasing the atmospheric concentrations of greenhouse gases and trapping more of the sun's energy near the Earth's surface. Meanwhile, our planet is warming at an unprecedented rate and our ecosystems are changing. If current greenhouse gas emission rates continue at the present rate, the impact to ecosystems and human welfare from the altered temperature and precipitation patterns will become more serious. Many nations have adopted policies to reduce greenhouse gas emissions, but a comprehensive and effective international climate treaty remains part of this continuing debate.

Climate Change: Causes, Effects, and Solutions, addresses these challenges, as well as what we know and do not know about climate change, in the three main sections: Climate Change: Past, Present, and Future; Ecological Effects of Climate Change; and Human Dimensions of Climate Change.

This book is for anyone seeking to understand the consequences of climate change and the steps that have been proposed to sustain a livable planet. It is an ideal text for courses in global climate change, as a supplement to courses in environmental studies, natural science, climatology, or physical geography, or for journalists, environmental policymakers, or just about everyone with an interest.

The author, John Hardy, is an internationally recognized speaker and a consultant to agencies and scientific research groups.

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

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