Carbon Dioxide Information Analysis Center
World Data Center for Atmospheric Trace Gases
Oak Ridge National Laboratory

CDIAC Communications

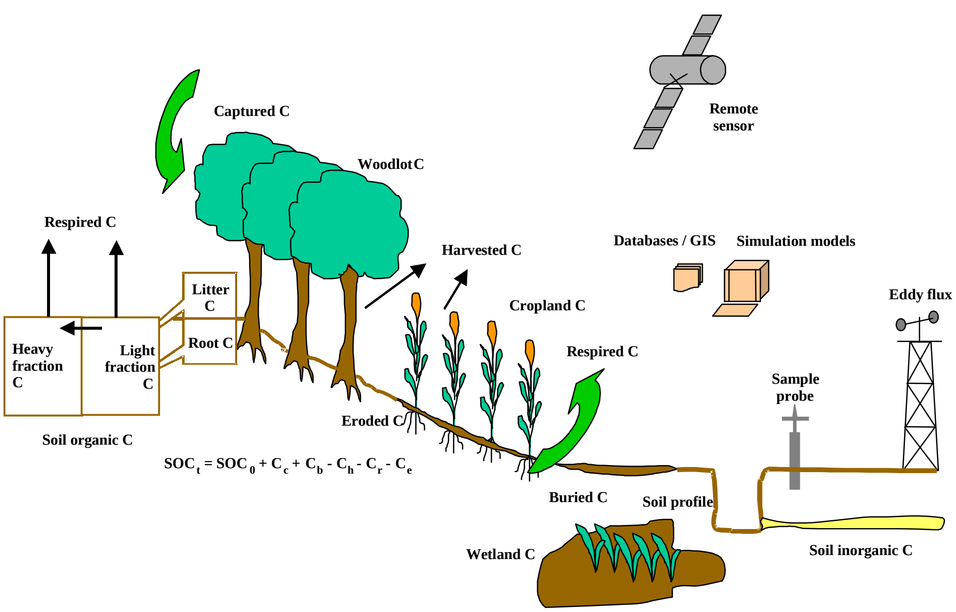
Monitoring and Verifying Changes of Organic Carbon in Soil

by Wilfred M. Post, R. Cesar Izaurralde, Linda K. Mann, Norman Bliss

Changes in soil and vegetation management can impact strongly on the rates of carbon (C) accumulation and loss in soil, even over short periods of time. Detecting the effects of such changes in accumulation and loss rates on the amount of C stored in soil presents many challenges. Consideration of the temporal and spatial heterogeneity of soil properties, general environmental conditions, and management history is essential when designing methods for monitoring and estimating future changes in soil C stocks. Several approaches and tools are required to develop reliable estimates of changes in soil C at scales ranging from the individual experimental plot to broad regional and national inventories.

There are two basic methods for determining soil C changes—direct methods and indirect methods. Direct methods include field sampling and laboratory measurements of total C,

Continued on p. 6



Elements of carbon dynamics and tools for monitoring and verifying changes in a heterogeneous landscape. Measurements made at the field scale using sampling and analysis methods and eddy covariance methods will require spatial and temporal extrapolation based on methods using information from geographic data, remote sensing, and appropriate computer simulation and data integration. (Abbreviations: SOC = soil organic carbon, 0 = initial time, t = time t, C_c = C captured by photosynthesis, C_b = C buried, C_h = C harvested (removed), C_r = C respired, C_e = C lost by erosion).

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What's Inside ...

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CDIAC's Program Manager:
Bobbi Parra

From the Director's Desk

Continuing at a busy and productive pace, CDIAC staff have published a number of new and updated data and information products since the last issue of *CDIAC Communications* was distributed. These data and information products are outlined in this issue of the newsletter.

In addition to the "core" CDIAC activities, such as quality-assuring, documenting, and publishing databases on global-change topics relating to emissions, atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases, and long-term climate records, staff have also been busy working in four special CDIAC "focus areas": AmeriFlux, FACE, NARSTO, and Ocean Data.

In this issue, we mention the AmeriFlux (the long-term study of carbon fluxes between the terrestrial biosphere of the Western Hemisphere and the atmosphere) databases available from CDIAC. AmeriFlux data management efforts were taken over by Tom Boden, assisted by Susan Holladay, following Antoinette Brenkert's move to Washington, D.C. As part of CDIAC's focus on FACE (Free-Air CO_2 Enrichment), we have a new Web site which begins the process of integrating the 30-something FACE sites around the world. In the Oceans Data area, Alex Kozyr, assisted by Linda Allison, continues to quality-assure and document databases on ocean carbon. Forrest Hoffman maintains Web sites for the Ocean Drifters project, as well as the Web sites for the multi-agency Global Change Data and Information System, and the U.S. National Assessment of the Potential Consequences of Climate Variability and Change. We have also continued our focus on the operation of the NARSTO Quality Systems Science Center to provide quality-assurance guidance for research on tropospheric ozone and particulates.

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

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

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

Bob

Robert M. Cushman

Trends Online

With the addition of the "Cloud" section, *Trends Online* contents now include records on:

- historical and modern atmospheric CO_2 concentrations
- estimates of global, regional, and national CO_2 emissions from the combustion of fossil-fuels, gas flaring, and cement production
- estimates of global anthropogenic methane emissions
- long-term atmospheric temperature records, and
- total cloud amounts over China

The following presents the new and updated information included in *Trends Online*.

Historical Isotopic Temperature Record from the Vostok Ice Core (*J.R. Petit et.al.*)
(http://cdiac.esd.ornl.gov/trends/temp/vostok/jouz_tem.htm)

Because isotopic fractions of oxygen-18 (^{18}O) and deuterium (D) in snowfall are temperature-dependent and a strong spatial correlation exists between the annual mean temperature and the mean isotopic ratio (^{18}O or δD) of precipitation, it is possible to derive ice-core climate records from the isotopic composition. This record was based on the 3623-m ice core drilled at the Vostok station in central east Antarctica, the deepest ice core ever recovered. The resulting core allowed the ice core record of climate properties at Vostok to be extended to 420,000 years BP.

From the extended Vostok record, Petit et al. concluded that present-day atmospheric burdens of carbon dioxide and methane seem to have been unprecedented during the past 420,000 years. Although the third and fourth climate cycles evident in the Vostok record are of shorter duration than the first two cycles, all four climate cycles show a similar sequence of a warm interglacial, followed by colder glacial events, and ending with a rapid return to an interglacial period. Minimum temperatures are within 1°C for the four climate cycles. The overall amplitude of the glacial-interglacial temperature change is ~8°C for the temperature above the inversion level and ~12°C for surface temperatures.

Global, hemispheric, and zonal temperature deviations derived from radiosonde records
(*J. K. Angell*)
(http://cdiac.esd.ornl.gov/trends/temp/angell/angell.html)

Data from a global network of 63 radiosonde stations were used to estimate global, hemispheric, and zonal annual and seasonal temperature deviations from 1958 through 1998. These estimates are categorized vertically (for the surface, troposphere, tropopause, low stratosphere, and the surface up to 100 mb) and horizontally (for the globe, the Northern and Southern Hemispheres, and the North and South Polar, North and South Temperate, North and South Subtropical, Tropical, and Equatorial latitudinal zones).

The data were obtained from values published in *Monthly Climatic Data for the World* and *Climatic Data for the World*, from the Global Telecommunications System (GTS) Network, and from National Center for Atmospheric Research files. Based on this network, Angell reported that during 1958–1998 the global, near-surface air temperature warmed by 0.14°C/decade and the troposphere layer warmed by 0.10°C/decade. The tropopause cooled in the extra tropics but warmed slightly in the tropics. The low-stratospheric layer cooled by about 0.4°C/decade in the tropics and extra tropics. At both the surface and in the troposphere, 1998 was the warmest year of the 41-year record, but when the influence of the powerful El Niño of 1997–1998 on these temperatures is taken into account, 1990 remains the warmest year of the record.

These data are also available in NDP-008 (see page 12).

Trends in Total Cloud Amount Over China

(*Dale P. Kaiser*)
(http://cdiac.esd.ornl.gov/trends/clouds/kaiser/kaiser98.html)

A new section on clouds has been added to *Trends Online*. The first dataset offered in this new section was contributed by CDIAC's Dale Kaiser. The cloud data were extracted from a database of 6-hourly weather observations, covering 196 stations from 1951 through 1994, and provided by the National Climate Center of the China Meteorological Administration to CDIAC through a bilateral research agreement.

Station and regional trends in annual and seasonal mean cloud amount clearly indicate decreasing total cloud amount over much of China during this period. Most stations in central, eastern, and northeastern China show statistically significant decreases of 1 to 3% sky cover per decade. The decreasing trends in cloud amount over some China regions are especially interesting in light of recent temperature trends observed over China, which have shown significant increasing trends in daily minimum temperatures since 1951. The largest increases in minimum temperature have been observed in the northeastern part of the country, precisely where the strongest decreasing trends in total cloud amount are observed. In China, it seems that some different mechanism(s) must be considered for understanding the observed increase in minimum temperatures, perhaps relating to atmospheric circulation or urbanization effects not fully removed from the temperature record.

Kyoto-Related Fossil-Fuel CO_2 Emission Totals

(*Gregg Marland et.al.*)
(http://cdiac.esd.ornl.gov/trends/emis/annex.htm)

Included in the carbon dioxide emissions section, this table shows emissions of CO_2 from fossil-fuel combustion and cement production in a format that is relevant for analyses relating to the Kyoto Protocol. The table lists emissions for those countries listed in Annex B of the Kyoto Protocol and for those countries not listed in Annex B (as well as providing lists of the countries in each category).

Atmospheric CO_2 records from NOAA/CMDL

(*Kirk Thoning et.al.*)
(http:// cdiac.esd.ornl.gov/trends/co2/nocm.htm)

The atmospheric carbon dioxide records from four sites in the National Oceanic and Atmospheric Administration/Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) continuous monitoring network have been updated to include data through 1998. Based on this continuous CO_2 record, since 1974 the annual average atmospheric CO_2 concentration at Point Barrow, Alaska, has risen from 333.94 parts per million by volume (ppmv) to 367.41 ppmv in 1998; at Mauna Loa, Hawaii, from 332.04 in 1976 to 366.49 ppmv in 1998; at Cape Matatula, American Samoa, from 331.45 in 1976 to 360.92 ppmv in 1996; and at the South Pole Observatory, from 329.33 in 1975 to 363.61 ppmv in 1998.

These observations are considered representative of "clean"concentrations in the well-mixed troposphere, free from confounding influences such as from vegetation or urban and industrial pollution; they quantify the increasing atmospheric concentrations of this most important greenhouse gas resulting from fossil-fuel combustion, land-use change, and cement production.

Focus Areas

Ocean Data

Carbon Dioxide In the North Atlantic Ocean

CARINA (CARbon Dioxide In the North Atlantic Ocean), a new global-change program, has been developed to synthesize CO_2 data collected in the North Atlantic for the last 15 years. CARINA was announced by marine scientists from eleven countries who attended the June 1999 workshop, “CO_2 in the North Atlantic” in Delmenhorst, Germany. CDIAC, represented at the workshop by Alexander Kozyr, was named as the primary data center for preservation and distribution of this final international North Atlantic data set. This activity will complement CDIAC’s role in PICES (North Pacific Marine Science Organization) working group 13 on CO_2, making CDIAC the leading data center in the world for oceanic CO_2 measurements.

Global Ocean Data Analysis Project

The GLobal Ocean Data Analysis Project (GLODAP) is a cooperative effort of investigators funded for synthesis and modeling projects through NOAA, DOE, and NSF. Cruises conducted as part of the World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), and NOAA Ocean-Atmosphere Exchange Study (OACES) over the last decade 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 against which future observational studies will be compared. They also provide tools for the direct evaluation of numerical ocean carbon models.

Free-Air CO_2 Enrichment

As part of CDIAC’s focus on FACE (Free-Air CO_2 Enrichment), the most sophisticated experimental approach to date for studying the effects of elevated CO_2 on vegetation, CDIAC developed and launched a new FACE Web page (http://cdiac.esd.ornl.gov/programs/FACE/face.html) which begins the process of integrating more than thirty FACE sites around the world. This Web site is part of an overall data and information management system being developed for FACE research as a collaborative effort between CDIAC and the FACE group at Brookhaven National Laboratory.

In collaboration with researchers at The Ohio State University, CDIAC also published numeric data packages that bring together results from many published CO_2-enrichment studies of woody and herbaceous vegetation.

Web Sites of Interest

Using various economic factors and forecast periods, calculate global and regional emission scenarios by source for CO_2 and CH_4 with CDIAC's IEA/ORAU Long-Term Global Energy-CO_2 Model (http://cdiac.esd.ornl.gov/ndps/cmp002pc.html).

Want to calculate how many pounds of CO_2 YOUR household produces daily? Try ABC's Carbon Dioxide Calculator (http://more.abcnews.go.com/sections/us/DailyNews/co2_calc1007.html).

Need more climate change and global warming information? Visit EPA's Global Warming site (http://www.epa.gov/globalwarming/) where special sites offering educational resources and classroom projects are available to students and teachers.

Have questions about climate change issues and the greenhouse effect? Get answers from the Climate Change Information Kit (http://www.unep.ch/iuc/submenu/infokit/factcont.htm) available from the United Nations Environment Programme's Information Unit for Conventions (IUC).

The Kids' and Teachers' Corner (http://www.yoto98.noaa.gov/kids.htm) of NOAA's International Year of the Ocean page provides lots to interest kids and teachers alike.

A "first of its kind" climate change search engine, dubbed the "Climate Ark" was recently released by the Ecological Enterprises, Inc. (EEI) (http://www.climateark.org/) that allows users to perform full-text searches and view the most targeted climate change information on the Web.

Monitoring and Verifying Changes of Organic Carbon In Soil

Continued from p. 1

various physical and chemical C fractions, and C isotopes. Carbon content changes are differences resulting from changes in land management and are expressed as the change in C amount on an area (kg m^{-2}) or volume basis (kg m^{-3}). The calculation is not difficult but requires awareness of the vertical and horizontal variability of soil properties in order to avoid systematic errors. Another promising direct method is eddy covariance measurement of CO_2 fluxes. The vertical component of air movements (eddies) over a vegetated surface can be isolated and quantitatively measured as can CO_2 concentration associated with each eddy. By correlating eddy size and CO_2 concentration for each upward and downward moving eddy, the net uptake or release of C by vegetation plus soil can be calculated. The accuracy and precision of this method is improving as more experience is gained.

Direct methods are essential for determining changes in soil C content for different land management treatments at the plot scale. To determine soil C pools and rates of change for large areas, it is necessary to extrapolate the relationships developed at the plot and field scale. Indirect methods are suitable for large areas. Indirect methods include simple and stratified accounting where plot estimates are multiplied by all applicable areas as determined by soil survey, land cover, climate, and other spatial data. Environmental and topographic relationships with C storage and change and modeling approaches can also be applied when available. Remote sensing and other geographical information are valuable in appropriately representing areas in these spatially aggregated estimation methods.

Accurate science-based methods are available for monitoring and verifying changes in soil C. Codifying a set of methods into protocols that can be used to account for C sequestration in public agreements or private trading contracts needs refinement and testing. The level of precision and effort required will vary with the purposes for which the measurements are applied. Examples of purposes include (a) determining compliance with local, regional, and national laws or treaties regulating CO_2 emissions; (b) evaluating joint implementation projects; and (c) assigning C credits and offsets. Current methods are effective for evaluating soil organic C changes at relatively low precision (20 to 50% error) and at widely spaced time intervals (minimum 3 to 5 years) with levels of effort that are reasonably affordable. Since relatively small amounts of C sequestered in soils could significantly reduce the rate of increase of atmospheric CO_2 and effectively buy time until low-cost methods for reducing CO_2 emissions are available, there will be considerable pressure to increase the reliability and precision of monitoring soil organic C changes on even shorter time scales.

Scientists are very interested in participating in the development of soil C monitoring protocols. However, in order to contribute to the development of these monitoring mechanisms, they need to know the economic and policy rules under which these mechanisms are anticipated to operate. A multi-sector, multi-discipline, and multi-national effort is required if we are to make monitoring and verification of C sequestration in soils a useful and widely used procedure.

Current and future technologies for monitoring soil carbon. (RS = Remote Sensing, LULC = Land Use and Land Cover, PAR=Photosynthetically Active Radiation, exp.= experimental, and SAR = Synthetic Aperature Radar)

Technology	Current (1999 – 2001)	Mid term (2002 – 2007)	Long term (2008 – 2020)
Direct methods			
Soil sampling and measurement	Reduce sampling errors, improve root estimates, bulk density measures	Non-destructive field measurement (exp.)	Non-destructive field measurement (routine, low cost)
Eddy covariance	60 sites world wide	Expand to characterize significant landcover types	Routine, part of automated stations (low cost, at weather stations with suitable fetch requirements)
Indirect methods			
Remote sensing	Low resolution LULC, absorbed PAR, hyperspectral (exp.), SAR (exp.)	High resolution, satellite-based hyper spectral, SAR, models (exp.)	High resolution, hyper spectral, SAR, models (routine)
C modeling	Models linked to databases; model intercomparisons	Models driven by RS input (exp.)	Real time simulation of land processes driven by RS
C accounting	Databases, maps, census, models (exp.)	Databases, maps, census, models, new sensors (refinement)	Databases, maps, census, models, new sensors (operational)

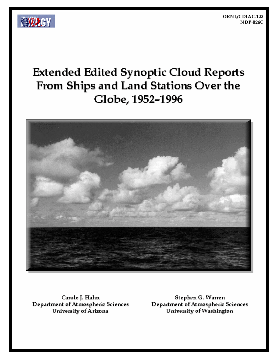
Acknowledgment
This article is excerpted from: Post, W.M.,[1] R.C. Izaurralde, [2] L.K. Mann, [1] and N. Bliss,[3] 1999. Monitoring and verifying soil organic carbon sequestration. pp. 41–66. In: (N. Rosenberg, R.C. Izaurralde, and E. L. Malone, eds.) *Carbon Sequestration in Soils: Science, Monitoring, and Beyond*. Proceeding of the St. Michaels Workshop, December 1998. Battelle Press.

[1]Oak Ridge National Laboratory, Oak Ridge, TN; [2] Pacific Northwest National Laboratory, Richland, WA; [3] EROS Data Center, Sioux Falls, SD

New and Updated Databases

CDIAC's data holdings provide coverage in 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.esd.ornl.gov/), from CDIAC's anonymous FTP area (cdiac.esd.ornl.gov), or requested directly from CDIAC on a variety of media (e.g., CD-ROM, 8mm tape, 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.

Extended Edited Synoptic Cloud Reports from Ships and Land Stations Over the Globe, 1952–1996



Hahn, Carole J., Department of Atmospheric Sciences, University of Arizona, Tucson, Arizona; Stephen G. Warren, Department of Atmospheric Sciences, University of Washington, Seattle, Washington
Prepared by Dale Kaiser, CDIAC

NDP-026C (1999) (http://cdiac.esd.ornl.gov/epubs/ndp/ndp026c/ndp026c.html)

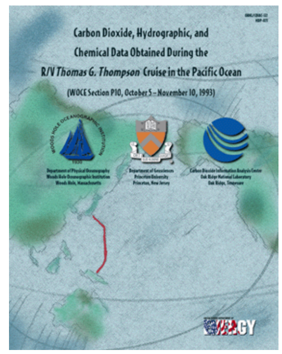
This fourth database in the NDP-026 series contains surface synoptic weather reports for the entire globe, gathered from various available data sets. These reports were then processed, edited, and rewritten to provide a single data set of individual observations of clouds, spanning 44 years (1952–1996) for ship data and 26 years (1971–1996) for land station data. In addition to the cloud portion of the synoptic report, each edited report also includes the associated pressure, present weather, wind, air temperature, and dew point (and sea surface temperature) over oceans.

Reports from the source data sets that did not meet certain quality control standards were rejected for the "Extended Edited Cloud Report Archive" (EECRA). Minor correctable inconsistencies within reports were edited for consistency. Cases of "sky obscured" were interpreted by reference to the present-weather code as to whether they indicated fog, rain, snow, or thunderstorm. Special coding was added to indicate probable nimbostratus clouds which are not specifically coded for in the standard synoptic code. Any changes made to an original report are also noted in the archived edited report so that the original report can be reconstructed if desired. This "extended edited cloud report" also includes the amounts, either inferred or directly reported, of low, middle, and high clouds, both overlapped and non-overlapped amounts. The relative lunar illuminance and the solar zenith angle associated with each report are also given, as well as an indicator that tells whether the recommended illuminance criterion was satisfied so that the "night-detection bias" for clouds can be minimized.

The EECRA contains over 72 million cloud observations from ships and 311 million from land stations, and the archive consists of 853 files of edited synoptic reports, one file for each month of data for land and ocean separately.

These data are useful for such applications as: (1) developing user-defined cloud climatologies for particular subtypes of clouds, or for different temporal and spatial resolutions than have been chosen for previously published atlases; (2) comparing satellite cloud retrievals with surface observations to help diagnose difficulties in cloud identification from satellites; and (3) relating formation of individual types of clouds to their meteorological environments.

Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Thomas G. Thompson* Cruise in the Pacific Ocean (WOCE Section P10, October 5–November 10, 1993)



Sabine, Christopher L., and Robert M. Key, Department of Geosciences, Princeton University, Princeton, New Jersey; Melinda Hall, Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
Prepared by Alexander Kozyr, CDIAC

NDP-071 (1999) (http://cdiac.esd.ornl.gov/oceans/ndp_071/ndp071.html)

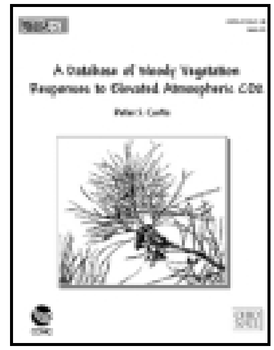
The oceans play a major role in the global carbon-cycle processes and are estimated to hold 38,000 gigatons of carbon, 50 times more than that in the atmosphere and 20 times more than that in plants, animals, and soil. If only 2% of the carbon stored in the oceans were released, the level of atmospheric CO_2 would double. Several large experiments have been conducted, and others are under way, to help us better understand the impact of the ocean in climate and climatic changes.

The R/V *Thomas G. Thompson* oceanographic expedition in the Pacific Ocean (Section P10), which began in Suva, Fiji, on October 5, 1993, and ended in Yokohama, Japan, on November 10, 1993, was conducted as part of the largest oceanographic experiment ever attempted, the World Ocean Circulation Experiment (WOCE). This database discusses the procedures and methods used during the R/V *Thomas G. Thompson* expedition to measure total carbon dioxide (TCO_2), total alkalinity (TALK), and radiocarbon ($\Delta^{14}C$), at hydrographic stations, as well as the underway partial pressure of CO_2 (pCO_2), including measurements of pressure, temperature, salinity [measured by conductivity, temperature, and depth sensor (CTD)], bottle salinity, bottle oxygen, phosphate, nitrate, nitrite, silicate, and the chlorofluorocarbons (CFC-11, CFC-12).

Section P10 is the westernmost section of the WOCE survey in the North Pacific Ocean. It is important for understanding the dynamics of the far western equatorial Pacific. The results from this cruise can be used to infer the relative magnitude of various tracers to the North Pacific from the South China Sea and the Sea of Japan. WOCE Section P10 also provides a transect across the Kuroshio Current which can be used to better understand the northward transport of heat, salt, and other important ocean tracers.

The underway surface measurements show a small outgassing of CO_2 at the equator. The TCO_2, TALK, and radiocarbon values show profiles typical for the North Pacific. TALK correlates strongly with salinity. ^{14}C correlates strongly with silicate. Deflection of the isolines of all parameters at the northern end of the cruise results from the Kuroshio Current. *WDC database*

A Database of Woody Vegetation Responses to Elevated Atmospheric CO_2

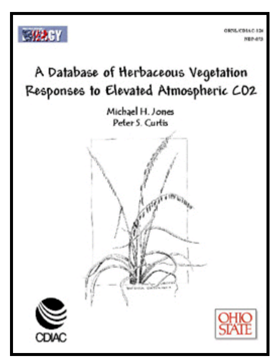


Curtis, Peter S., Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus, Ohio
Prepared by Robert M. Cushman and Antoinette L. Brenkert, CDIAC

NDP-072 (1999) (http://cdiac.esd.ornl.gov/epubs/ndp/ndp072/ndp072.html)

Produced to perform a statistically rigorous meta-analysis of research results on the response by *woody* vegetation to increased atmospheric CO_2 levels, this multiparameter database of responses was compiled from the published literature and unpublished reports and released as an enhancement to the previously published database, *A Comprehensive Database of Woody Vegetation Responses to Elevated Atmospheric CO_2* (DB-1018). Eighty-four independent CO_2-enrichment studies, covering 65 species and 35 response parameters, met the necessary criteria for inclusion in the database: reporting mean response, sample size, and variance of the response (either as standard deviation or standard error). Physiological "acclimation" or "downward regulation" of photosynthetic rates, stomatal conductance, dark respiration, and water-use efficiency of plants exposed to elevated CO_2 levels can be analyzed. The effects of environmental factors (e.g., nutrient levels, light intensity, temperature), stress treatments (e.g., drought, heat, ozone, ultraviolet-B radiation), and the effects of experimental conditions (e.g., duration of CO_2 exposure, pot size, type of CO_2 exposure facility) on plant responses to elevated CO_2 levels can be also be explored with this database.

A Database of Herbaceous Vegetation Responses to Elevated Atmospheric CO_2



Jones, Michael H., and Peter S. Curtis, Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus, Ohio
Prepared by Robert M. Cushman and Antoinette L. Brenkert, CDIAC

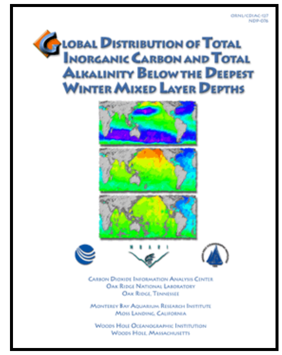
NDP-073 (1999) (http://cdiac.esd.ornl.gov/epubs/ndp/ndp073/ndp073.html)

This database, which accompanies the previously discussed database, NDP-072, is used to support a meta-analysis of research results on the response by *herbaceous* vegetation to increased atmospheric CO_2 levels, and was also compiled from the published literature.

Seventy-eight independent CO_2-enrichment studies, covering 53 species and 26 response parameters, reported mean response, sample size, and variance of the response. An additional 43 studies, covering 25 species and 6 response parameters, did not report variances.

This database may also be used to explore the effects from many of the same environmental factors, stress treatments, and the effects of experimental conditions on plant responses to elevated CO_2 levels, as were investigated in NDP-072.

Global Distribution of Total Inorganic Carbon and Total Alkalinity Below the Deepest Winter Mixed Layer Depths



Goyet, Catherine, and Richard J. Healy, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts; and John P. Ryan, Monterey Bay Aquarium Research Institute, Moss Landing, California
Prepared by Alexander Kozyr, CDIAC

NDP-076 (2000) (http://cdiac.esd.ornl.gov/oceans/ndp_076/ndp076.html)

Modeling the global ocean-atmosphere CO_2 system is becoming increasingly important to greenhouse gas policy. These models require initialization with realistic three- dimensional (3-D) oceanic carbon fields. This report presents an approach to establishing these initial conditions from an extensive global database of ocean CO_2 system measurements and well-developed interpolation methods. These methods are limited to waters below the deepest mixed layer. The data used for these interpolations include the recent high-quality data sets from the World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), and Ocean-Atmosphere Carbon Exchange Study (OACES) programs. Prior to analysis, all carbon data were adjusted to the established reference materials for oceanic carbon dioxide measurements (http://www-mpl.ucsd.edu/people/adickson/CO2_QC/). The interpolation methodology employs correlation between CO_2 system properties and other more widely measured properties: potential temperature, salinity, and apparent oxygen utilization. The correlations are computed for each profile, and the coefficients are interpolated to the 1°×1°×32 vertical-layer grid at a monthly temporal resolution. Finally, the gridded coefficients are applied to a global monthly climatology of ocean temperature, salinity, and oxygen to compute total CO_2 (TCO_2) and total alkalinity (TALK) for the 3-D grid.

This approach offers advantages over spin up of a single profile in defining spatial variation in CO_2 system properties because it reduces initialization time and provides a more accurate carbon field. The results provide an unprecedented "view" of the global distribution of TALK and TCO_2 in the ocean. These results, as well as those from the monthly mixed layer depths, can be used in diagnostic and prognostic global ocean models.

The interpolated data set includes seasonal TCO_2 and TALK fields, as well as the coefficients used to estimate these concentrations, and the monthly mixed layer depths. *WDC database*

Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958–1998

Angell, J. K., Air Resources Laboratory, National Oceanic and Atmospheric Administration, Silver Spring, Maryland
Prepared by Dale Kaiser and Sonja Jones, CDIAC

NDP-008 (updated 1999) (http://cdiac.esd.ornl.gov/ndps/ndp008.html)

Surface temperatures and thickness-derived temperatures from a global network of 63 radiosonde stations were used to estimate annual and seasonal temperature deviations (calculated relative to a 1958-1977 reference period mean) over the globe and several zonal regions from 1958 through 1998.

Most of the values are column-mean temperatures obtained from the differences in height between constant-pressure surfaces at individual radiosonde stations. The pressure-height data before 1980 were obtained from published values in *Monthly Climatic Data for the World*. Between 1980 and 1990, Angell used data from both the *Climatic Data for the World* and the Global Telecommunications System (GTS) Network received at the National Meteorological Center. Between 1990 and 1995, the data were obtained only from GTS, and since 1995 the data have been obtained from National Center for Atmospheric Research files. These temperature deviations may be used to analyze long-term temperature trends for a layer of the atmosphere (i.e., surface, troposphere, tropopause, and low stratosphere), a region (i.e., polar, temperate, subtropical, and equatorial), a hemisphere, or the globe.

Additional information, including updated methods, trends, and graphics, are described in CDIAC's *Trends Online* (see page 3).

Atmospheric Methyl Chloride

Khalil, M.A.K., Department of Physics, Portland State University, Portland, Oregon; and R.A. Rasmussen, Department of Environmental Science and Engineering, Oregon Graduate Institute, Portland, Oregon
Prepared by Tom Boden, CDIAC

(2000) (http://cdiac.esd.ornl.gov/epubs/other/methylchl.html)

Monthly average concentrations of atmospheric methyl chloride from seven locations throughout the polar, middle, and tropical latitudes of both hemispheres are provided in this database. The seven primary sites include Pt. Barrow, Alaska; Cape Kumukahi and Mauna Loa, Hawaii; Cape Matatula, Samoa; Cape Grim, Tasmania; and the South Pole and Palmer Station, Antarctica. Concentration measurements from these seven sites cover a period of 16 years (1981–1997). Monthly data and vertical distributions at 20 short-term sites, from various latitudes, were also measured between 1987–1989.

Air samples were collected from various sites in stainless steel flasks and methyl chloride concentrations were measured using an Electron Capture Gas Chromatograph. Concentrations are reported as mixing ratios in dry air. The concentrations are determined by using a set of calibration standards that are referenced against a primary standard which is also used to establish the absolute concentration. The primary standards were prepared by the investigators in the absence of an available standard from a centralized location.

These data are useful in global methyl chloride budget analyses and for determining the atmospheric distribution and trends of methyl chloride and estimating the total emissions at various latitudes. *WDC database*

AmeriFlux Data

Sponsored by the Environmental Sciences Division of DOE's Office of Biological and Environmental Research, CDIAC provides the data management for AmeriFlux (Long-term CO_2 flux measurements of the Americas). Long-term measurements of CO_2, water vapor, and energy exchange through the eddy covariance technique from different ecosystems are integrated into consistent, quality assured, and fully documented data sets.

The following presents the *final* databases offered in CDIAC's AmeriFlux data archive. Detailed information on the data management is also located on the AmeriFlux Web site (http://cdiac.esd.ornl.gov/programs/ameriflux/):

AmeriFlux CO_2, water vapor, and energy exchange measurements from the Walker Branch Watershed, Tennessee: 1995–1998 (March 2000) Author: Baldocchi, D.D., Wilson, K.

AmeriFlux CO_2, water vapor, and energy exchange measurements from Ponca City wheat site, Oklahoma: 1996–1997 (February 2000) Author: Verma, S.B.

AmeriFlux CO_2, water vapor, and energy exchange measurements from Shidler tallgrass Prairie site, Oklahoma: 1996–1997 (February 2000) Author: Verma, S.B.

AmeriFlux CO_2, water vapor, and energy exchange measurements from Metolius Natural Research Area old growth ponderosa pine site, Oregon: 1996–1997 (October 1999) Author: Anthoni, P.M., Baldocchi, D.D., Law, B.E, and Unsworth, M.H.

Awards and Accomplishments

CDIAC recently received two awards of Merit (printed copy and online version) for *CDIAC Communications* (http://cdiac.esd.ornl.gov/newsletr/ccindex.html), submitted by Sonja B. Jones and Karen N. Gibson in the East Tennessee Society for Technical Communication (STC) Chapter's 1999 Technical Publications and Art Competition.

Alex Kozyr presented the poster *Data Management Provided by the Carbon Dioxide Information Analysis Center for the U.S. Department of Energy CO_2 Ocean Survey During WOCE/JGOFS Cruises* (co-authored with Tom Boden) at the International Symposium on Carbon Cycle in the North Pacific (Nagoya, Japan). The poster, which describes CDIAC's efforts to quality-assure, document, and distribute ocean carbon data, received the symposium's "Most Important Poster" award.

The ORNL Environmental Sciences Division presented Karen Gibson with the 1999 Distinguished Technical Achievement Award for her outstanding technical support to CDIAC.

The ORNL Computing, Information and Networking Division named Jim Simmons as the winner of the Outstanding Customer Service Award for Networking and Workstation Services "for systems administration support to the CDIAC."

Dale Kaiser was elected President of the Smoky Mountain Chapter of the American Meteorological Society.

CDIAC Publications

Carbon dioxide-related publications are available from CDIAC while supplies last. Please note: Several publications listed in prior versions of the catalog are no longer distributed by CDIAC. DOE personnel and DOE contractors should request those copies from the Office of Scientific and Technical Information (OSTI), P.O. Box 62, Oak Ridge, TN 37831 (http://www.osti.gov/). Other individuals may purchase copies from the National Technical Information Service (NTIS) (703-487-4650 or http://www.ntis.gov/) in microfiche or hard copy; prices will vary with the number of pages.

Publications, Presentations, and Awards

Robert M. Cushman, CDIAC

ORNL/CDIAC-101 (2000) (http://cdiac.esd.ornl.gov/epubs/CDIAC/cdiac101/pubslist.htm)

Originally published in 1997, this online publication was updated to include the journal articles, book and proceedings chapters, numeric data packages and online databases, and other ORNL and DOE reports that have been published by CDIAC since the original version became available. Also included in this publication are global change-related presentations made by CDIAC staff and awards that have been presented to CDIAC since its inception in 1982.

Comparison of the Carbon System Parameters at the Global CO_2 Survey Crossover Locations in the North and South Pacific Ocean, 1990–1996

Feely, Richard A., Marilyn F. Lamb, Dana J. Greeley, NOAA, Pacific Marine Environmental Laboratory, Seattle, Washington; and Rik Wanninkhof, NOAA, Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
Prepared by Linda Allison and Dana Griffith, CDIAC

ORNL/CDIAC-115 (1999) (http://cdiac.esd.ornl.gov/epubs/CDIAC/cdiac115.htm)

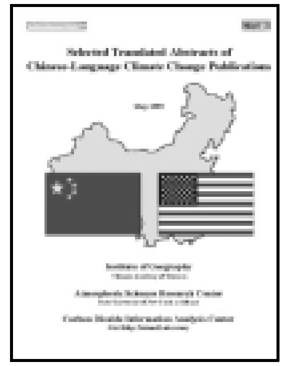
As part of a collaborative program to measure global ocean carbon inventories and provide estimates of the anthropogenic CO_2 uptake by the oceans, NOAA and DOE cosponsored the collection of ocean carbon measurements via the U.S. Joint Global Ocean Flux Study (JGOFS) Program. Investigators supported by these funding agencies collaborated to examine data collected during the World Ocean Circulation Experiment (WOCE) and Ocean-Atmosphere Carbon Exchange Study (OACES) cruises.

The Pacific Ocean cruises in this report occurred from 1990 through 1996 and overlapped in the North and South Pacific Ocean. Four parameters of the oceanic CO_2 system from 30 crossover locations were compared to ensure that a consistent global data set emerged from the survey cruises. These parameters included dissolved inorganic carbon (DIC), fugacity of CO_2 (fCO_2), total alkalinity (TALK), and pH, along with salinity and dissolved oxygen (O_2).

The world's oceans, widely recognized to be the major long-term control on the rate of CO_2 increases in the atmosphere, are believed to be absorbing about 2.0 GtC yr^{-1} (nearly 30 to 40% of the annual release from fossil fuels). Our present understanding of oceanic sources and sinks for CO_2 is derived from a combination of field data that are limited by sparse temporal and spatial coverage and model results that are validated by comparisons with oceanic bomb ^{14}C profiles.

The results from the Pacific Ocean cruises indicate that for DIC, fCO_2, and pH, the agreements at most crossover locations are well within the design specifications for the global CO_2 survey; whereas, in the case of TALK, the agreement between crossover locations is not as close.

Selected Translated Abstracts of Chinese-Language Climate Change Publications



Ge Quansheng, Zhang Peiyuan, Liu Xiuping, Zhang Xueqing, Chen Yuan, Peng Guitang, and Zheng Jingyun, Institute of Geography, Chinese Academy of Sciences, Beijing, China; Wei-Chyung Wang, Atmospheric Sciences Research Center, State University of New York at Albany; and Robert M. Cushman and Marvel D. Burtis, CDIAC

ORNL/CDIAC-117 (1999)
(http://cdiac.esd.ornl.gov/epubs/catalog/CDIAC/cdiac117/cdiac117.html)

Much of the Chinese literature that has been published on the topic of global climate change is available in English to western researchers, but much of it is not. This report contains the English-translated abstracts of important global climate change Chinese-language literature published between 1995 and 1998. Topics included in this compilation cover adaptation, ancient climate change, climate variation, the East Asia monsoon, historical climate change, impacts, modeling, and radiation and trace-gas emissions. In addition to the bibliographic citations and abstracts translated into English, this report also presents the original citations and abstracts in Chinese.

Reference Links

American Meteorological Society (AMS), Smoky Mountain Chapter - http://www.kornet.org/smc-ams/

Brookhaven National Laboratory (BNL) FACE Group - http://www.face.bnl.gov/

CARbon Dioxide in the North Atlantic Ocean (CARINA) - http://www.ifm.uni-kiel.de/ch/carina/index.htm

Chinese Academy of Sciences (CAS), Institute of Geography - http://159.226.115.2/

China Meteorological Administration (CMA) - http://www.cma.gov.cn/

EROS Data Center - http://edcwww.cr.usgs.gov/

Global Change Data and Information Systems (GCDIS) - http://globalchange.gov/

GLobal Ocean Data Analysis Project (GLODAP) - http://cdiac.esd.ornl.gov/oceans/glodap/index.html

The Global Telecommunications System (GTS) Network - http://www.wmo.ch/web/www/TEM/gts.html

Joint Global Ocean Flux Study (JGOFS) - http://ads.smr.uib.no/jgofs/jgofs.htm

Monterey Bay Aquarium Research Institute (MBARI) - http://www.mbari.org/

National Center for Atmospheric Research (NCAR) - http://www.ncar.ucar.edu/ncar/

National Climate Center, Chinese Meteorological Administration - http://ncc.cma.gov.cn/index.htm

National Oceanic and Atmospheric Administration (NOAA) - http://www.noaa.gov/

NOAA/Air Resources Laboratory (ARL) - http://www.arl.noaa.gov/

NOAA/Atlantic Oceanographic and Meteorological Laboratory (AOML) - http://www.aoml.noaa.gov/

NOAA/Climate Monitoring and Diagnostics Laboratory (CMDL) - http://www.cmdl.noaa.gov/

NOAA/Pacific Marine Environmental Laboratory (PMEL) - http://www.pmel.noaa.gov/

National Science Foundation (NSF) - http://www.nsf.gov/

North Pacific Marine Science Organization (PICES) - http://pices.ios.bc.ca/

Oak Ridge National Laboratory (ORNL) - http://www.ornl.gov/

Official Web site of the Third Conference of the Parties to the UNFCCC - http://www.cop3.de/

ORNL/Environmental Sciences Division (ESD) - http://www.esd.ornl.gov/

ORNL/Computing, Information and Networking Division - http://www.ornl.gov/cind/

Ocean-Atmosphere Carbon Exchange Study (OACES) - http://www.pmel.noaa.gov/co2/co2-home.html

Ohio State University (OSU) - http://www.osu.edu/

OSU/Department of Evolution, Ecology, and Organismal Biology - http://www.biosci.ohio-state.edu/~eeob/index.html

Oregon Graduate Institute, Department of Environmental Science and Engineering - http://www.ese.ogi.edu/

Pacific Northwest National Laboratory (PNNL) - http://www.pnl.gov/

Portland State University, Department of Physics - http://physics.pdx.edu/index.htm

Princeton University, Department of Geosciences - http://geoweb.princeton.edu/

Project NOPP (National Oceanographic Partnership Program) Drifters - http://drifters.doe.gov/

Society for Technical Communications (STC) - http://www.stc-va.org/

State University of New York-Albany, Atmospheric Sciences Research Center - http://www.asrc.cestm.albany.edu/

University of Arizona, Department of Atmospheric Sciences - http://www.atmo.arizona.edu/

University of Washington, Department of Atmospheric Sciences - http://www.atmos.washington.edu/

U.S. Department of Energy (DOE) - http://www.doe.gov/

DOE/Environmental Sciences Division (ESD) - http://www.er.doe.gov/production/ober/ESD_top.html

DOE/Office of Biological and Environmental Research (OBER) - http://www.er.doe.gov/production/ober/ober_top.html

U.S. National Assessment of the Potential Consequences of Climate Variability and Change - http://www.nacc.usgcrp.gov/

UT-Battelle, LLC - http://www.ut-battelle.com/

Woods Hole Oceanographic Institution (WHOI) - http://www.whoi.edu/

WHOI/Department of Physical Oceanography - http:// www.whoi.edu/science/PO/dept/

World Ocean Circulation Experiment (WOCE) Hydrographic Program - http://whpo.ucsd.edu/

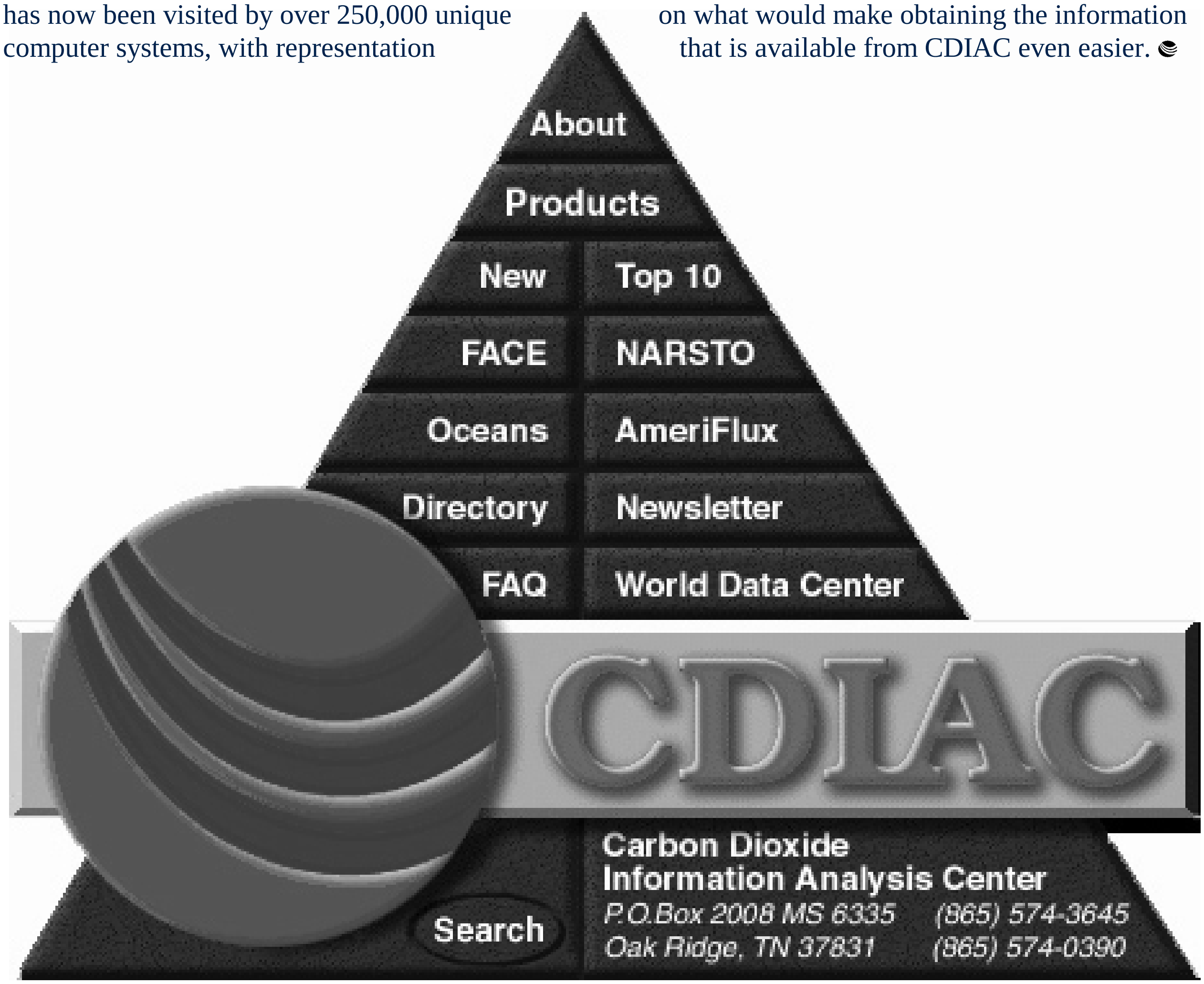
NOTE!!

Internet Sites listed in *CDIAC Communications* are Web sites that were available at the time of publication. Internet users should realize that Web sites come and go.

CDIAC's Home Page

CDIAC's home page design is basically the same as that which premiered in the fall of 1996. However, we trust that the minute changes we have since incorporated have enabled users to find the information they are interested in more quickly or helped them in locating other sites with useful and relevant information. Since becoming an online presence in the mid-1990s, CDIAC's Web site has now been visited by over 250,000 unique computer systems, with representation from 157 domains. The number of data and information files that have been accessed has grown into the millions.

As we continue updating and building our repertoire (as well as our online data and information holdings), we encourage users to contact us concerning our data and information holdings, the navigation of our site, or for ideas on what would make obtaining the information that is available from CDIAC even easier.



http://cdiac.esd.ornl.gov/

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

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