

Data Management for the North American Carbon Program



Workshop Report
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January 25–27, 2005



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Acknowledgments

This Workshop Report is dedicated to Dave Shultz. The initial planning for this data workshop was led by David J. Shultz, a USGS scientist who passed away tragically on April 8, 2004. Dave was one of the first people to commit his time to the challenge of integrating diverse data from numerous sources in order to achieve the goals of the North American Carbon Program (NACP). He was not a specialist in data management, but he volunteered to initiate this workshop because he recognized its importance. With his open questions and dry wit, Dave represented the need for data access and integration to be available to all participants in the NACP.

The workshop participants would like to thank Melanie Whitmire (UCAR, Boulder, Colorado) for outstanding coordination and logistical support for the NACP Data Management Planning Workshop. Support for this workshop was provided by the Carbon Cycle Interagency Working Group, which is comprised of six agencies that contribute to the U.S. Carbon Cycle Science Program. The agencies are DOE, NASA, NOAA, NSF, USDA, and USGS.



Contents

Executive Summary	1
Introduction.....	3
Workshop Objectives and Approach	5
Workshop Recommendations	7
Design of the NACP Data Management System.....	7
Data Policy	10
Quality Assurance of NACP Data and Data Products	11
Resources Required	12
Establish Coordination between Agencies and Data Centers.....	13
How to Exert Oversight and Management of the NACP Data Management Program	13
Integrating Human Dimensions into NACP	15
References.....	17
Appendix A. Charge for the Data Management Workshop.....	A-1
Appendix B. Workshop Agenda	B-1
Appendix C. Breakout Group Questions	C-1
Appendix D. Posters Presented at the Workshop	D-1
Appendix E. Workshop Participants.....	E-1



Executive Summary

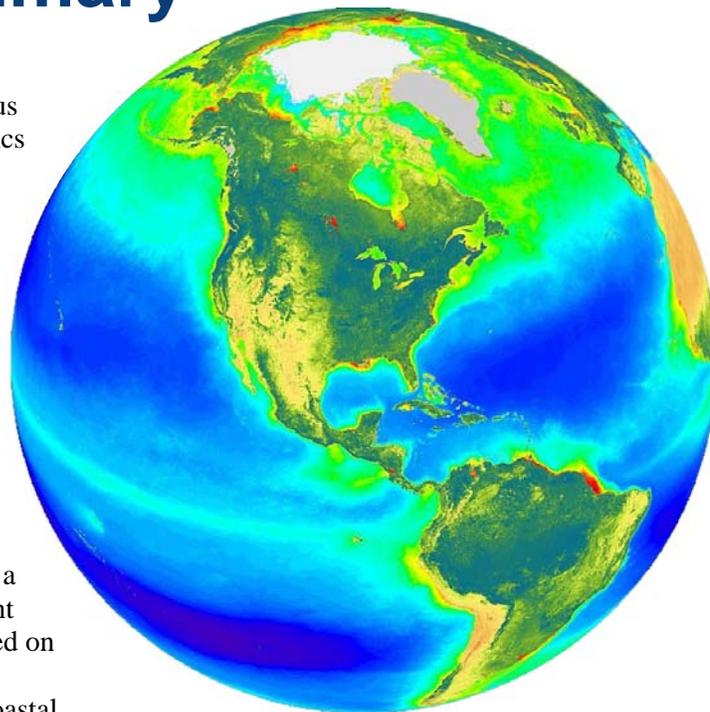
The Carbon Cycle Interagency Working Group (CCIWG) is coordinating an ambitious research program to examine carbon dynamics in North America [North American Carbon Program (NACP)]. The CCIWG recognizes the need for an integrated data and information management system for NACP that will acquire, integrate, quality assure, and archive the complex data needed for the program.

To develop the requirements and architecture for the data management program, the CCIWG held a community planning workshop in New Orleans, Louisiana on January 25-27, 2005. The objectives of this workshop were to develop a design for a comprehensive data management system for the NACP. The workshop focused on terrestrial carbon cycling. The CCIWG is planning a future workshop to address the coastal interface between the North American continent and the oceans.

The workshop agenda was organized around introductory presentations, case studies describing lessons learned from similar continental-scale projects, breakout group discussions, plenary discussions, and a poster session. The breakout groups addressed questions concerning four themes of data management: (1) data accumulation, (2) quality assurance (QA)/quality control (QC) for NACP data products, (3) data distribution and access, and (4) value-added products. The workshop provided 17 recommendations:

Design of the NACP Data Management System

1. The NACP Office should establish a Web site describing all NACP investigations (major federal agency programs, projects, and networks participating in NACP as well as individual NACP investigators) to help coordinate NACP projects (near-term action).
2. The NACP Science Steering Group (SSG), working with NACP investigators, should identify priority data products and services, including socio-economic data and data for decision support, required to address NACP



Source: D. E. Wickland, "U.S. Climate Change Science Program: Carbon Cycle Science Program," January 25, 2005.

- research questions and when those products and services are needed (near-term action).
3. The SSG needs to convene a subcommittee to further clarify the requirements and options for the NACP Data Management System, based on the workshop discussions (near-term action).
4. The NACP Office should establish a centralized Web-based metadata clearinghouse that contains an index of metadata, data, and services with links to distributed data (near-term action).
5. The CCIWG, in conjunction with the SSG, needs to establish a process for identifying and prioritizing the production of value-added products relevant to NACP objectives.

NACP Data Policy

6. The SSG should develop a data policy regarding sharing of data collected under the auspices of the NACP, access to NACP data by the broader scientific community and by the public, and expectations for short- and long-term data archive. The CCIWG should work with the SSG to develop effective means

for implementing this data policy (near-term action).

Quality Assurance of NACP Data and Data Products

7. The SSG needs to establish and implement protocols for QA, including establishing definitions and standards for data QA and QC, uncertainties, error analyses, and documenting the quality of the data products.
8. NACP should publish peer-reviewed data reports for documenting primary NACP data sets.

Resources Required

9. The CCIWG should investigate innovative and efficient ways of engaging existing data centers in the data management activities of NACP.
10. The NACP participating agencies need to balance the NACP data requirements that result from numbers 1-5 above with resources available (“right-size” the data management system).
11. NACP participating agencies should identify resources to design and develop an NACP Web portal and metadata editor (near-term action)
12. NACP participating agencies should fund dedicated staff to work with investigators on data and metadata issues (near-term action).
13. The NACP participating agencies need to ensure that NACP Principal Investigators (PIs) allocate sufficient resources to support their individual project’s data management activities.

Establish Coordination between Agencies and Data Centers

14. The CCIWG needs to establish data coordinating agreements (MOUs) with U.S. agencies, Mexico, Canada, intergovernmental agencies, and international scientific bodies where necessary and feasible.

How to exert Oversight and Management of the NACP Data Management Program

15. The CCIWG needs to establish a Data Management Working Group comprised of data producers, data users, and data system developers to provide coordination and integration of data management with research activities. (near-term action)
16. NACP funding agencies should develop the means to make the NACP data management guidelines and policies as effective as possible.
17. The CCIWG should promote the coordination of data management and data synthesis through annual or semiannual modeling / analysis workshops for regional intensive campaigns or North America-wide studies.

Integrating Human Dimensions into NACP

During the course of the workshop, participants recognized that social sciences and human dimensions have not been adequately incorporated into NACP. Even though this topic was not in the purview of the data management planning workshop, the workshop offers the recommendation that the CCIWG needs to include full consideration of human dimensions of the carbon cycle, by incorporating social sciences into the research objectives for NACP and by forming a working group for the stakeholder community. In addition, the workshop recommended that NACP funding agencies should develop research solicitations to enhance human dimension engagement on carbon science issues.

Introduction

The Carbon Cycle Interagency Working Group (CCIWG) is undertaking an ambitious research program to examine carbon dynamics in North America — the North America Carbon Program (NACP). NACP is a multidisciplinary research program established to obtain scientific understanding of North America's carbon sources and sinks, of changes in carbon stocks needed to meet societal concerns, and to provide tools for decision makers (Wofsy and Harriss 2002; Denning et al., 2005). Successful execution of the NACP will require an unprecedented level of coordination among observational, experimental, and modeling efforts regarding terrestrial, oceanic, atmospheric, and human components of the carbon cycle. The NACP is supported by a number of different federal agencies through a variety of intramural and extramural funding mechanisms and award instruments. NACP will rely upon a rich and diverse array of existing observational networks, monitoring sites, and experimental field studies in North America and its adjacent oceans. Integrating these different program activities and maximizing synergy among them will require

expert guidance beyond the norm for large field programs in Earth system science and global climate change. At the heart of the NACP strategy is an integrated data and information management system that enables researchers to access, understand, use, integrate, analyze, and archive large volumes of diverse high-quality data at multiple thematic, temporal, and spatial scales.

To develop the requirements and architecture for the NACP data management program, the CCIWG held a community planning workshop in New Orleans, Louisiana, on January 25 – 27, 2005. The objectives of this workshop were to develop a design for a comprehensive data management system for the NACP. The charge for the NACP Data Management Planning Workshop can be found in Appendix A.

This workshop report includes recommendations to the CCIWG about the data management system design; the resources required; interfaces between agencies and data centers; and how to exert oversight and management of the NACP Data Management Program.



Source: D. E. Wickland, "U.S. Climate Change Science Program: Carbon Cycle Science Program," January 25, 2005.



Workshop Objectives and Approach

The overall goal of the workshop was to develop a comprehensive architecture for an NACP Data Management System.

The participants were asked to produce a concise set of recommendations for the design, development, and implementation of the NACP Data Management System that addresses available options and resource requirements. The approach was to develop an NACP data management capability that reflects the needs of the user community, is created in a reasonable time frame, and is universally accepted as a value-added capability to those doing work (researchers, decision makers, policy makers, etc.).

The workshop participants were asked to use the following goal as the basis for their deliberations:

The goal of the NACP Data Management System is to ensure that data products, information, and tools required to address science questions are available in convenient forms when needed.

The data system should have the following functions:

- ◆ encourage the adequate storage and documentation of data by collaborating projects;
- ◆ find and access relevant data and information;
- ◆ integrate data from a variety of sources that may be reported in differing ways and/or cover differing spatial and temporal domains;
- ◆ plan for a broad spectrum of data types;
- ◆ process to assure and document data quality and uncover errors early, to allow proper interpretation and use;
- ◆ support intensive field campaigns;
- ◆ make efficient use of existing agency data management infrastructure and resources;
- ◆ ensure close coordination between the data group(s) and the producers and users of the data products; and
- ◆ provide for long-term archival of key data and results.

Because the data system will most likely be funded with reprogrammed base funding, the participants were requested to incorporate to the fullest extent possible existing data management capabilities, organizations, infrastructure, and resources. In addition, the NACP data system architecture should be dynamic and flexible to make full use of existing technology as well as beneficial future technologies.

The workshop focused primarily on terrestrial carbon cycling and did not consider data management issues associated with the coastal waters of North America, even though several representatives from the ocean community participated in the workshop. The CCIW is planning a joint meeting of NACP and the Ocean Carbon and Climate Change (OCCC) program to specifically address the coastal interface between the North American continent and the oceans.

In developing their recommendations, the workshop participants were asked to identify near-term activities as well as long-term activities.

Workshop Agenda

The NACP Data Management Planning Workshop was organized around plenary presentations, breakout group discussions, plenary discussions, and a poster session. The workshop agenda is attached as Appendix B.

The introductory session provided background on NACP, the purpose of the workshop, and a strategy for managing data and information for NACP. In addition, two case studies [Vegetation Ecosystem Modeling and Assessment Program (VEMAP) and CarboEurope] illustrate how other programs have dealt with large-volume data management issues similar to those facing NACP. A third case study on the Joint Global Ocean Flux Study (JGOFS) was submitted, but the presenter was snowbound and could not travel to the meeting. All of the presentations are posted on the Workshop Web Site:

<http://www.nacarbon.org/nacp/dm.html> .

During the course of the workshop, four breakout groups met to address components of the data management strategy:

1. Data Accumulation
2. QA/QC for NACP Data Products
3. Data Distribution and Access
4. Value-Added Products

The questions each breakout group considered are included as Appendix C. The groups took a phased approach in their discussions, reporting back to plenary several times during the workshop. This approach enabled all participants to hear the progress being made and to build on the other groups' discussions.

A poster session provided an opportunity to share experiences on NACP data-related topics

such as approaches for managing data streams from field, airborne, and remote sensing campaigns; preparation of value-added products; tools for processing, analyzing, and visualizing data; and advances in information technology. A list of the posters presented at the workshop is included as Appendix D.

Participants

The CCIWG and the steering committee for the meeting assembled 57 representatives of the NACP investigator community, the major data sets and data management systems likely needed by the program, and Canadian and Mexican agencies. The list of workshop participants is included as Appendix E.



Source: <http://www.fluxnet.ornl.gov/fluxnet/fluxpictures.cfm>

Workshop Recommendations

Design of the NACP Data Management System

1. The NACP Office should establish a Web site describing all NACP investigations (major federal agency programs, projects, and networks participating in NACP as well as individual NACP investigations) to help coordinate NACP projects (near-term action).

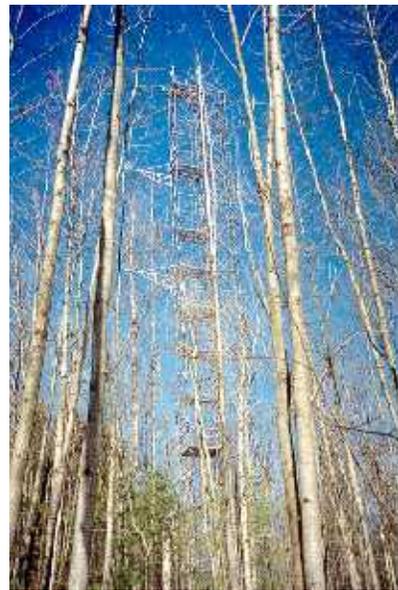
The workshop participants felt that a Web-based comprehensive list of all NACP research investigations was critically needed for NACP activities, especially the upcoming midcontinent intensive field campaign, as well as NACP-wide work. Such a collection of project descriptions should be designed for optimizing scientific synergy among NACP investigations and participating programs, projects, and networks. The list, which should be compiled in close coordination with NACP investigators, should facilitate presentation of NACP projects and linkages to investigator Web sites.

2. The NACP Science Steering Group (SSG), working with NACP investigators, should assume responsibility to identify data management services and functions and priority data products, including socio-economic data and data for decision-support, required to address NACP research questions and when those products and services are needed (near-term action).

The specific requirements for the data system and data products will need to be derived by the SSG from the NACP research objectives as well as the individual research projects funded under NACP.

In this effort to identify priority data products, the SSG can build on the Data Management Section of the *NACP Strategic Implementation Strategy Plan* (2005), which describes model output products, atmospheric constituents, flux products, land cover / land use change products, carbon inventory products, and data required for diagnostic and prognostic models. Many of the required data streams exist today, but are not produced consistently at the time and space resolution needed, and the data are not assembled

into an integrated set for data assimilation (Wofsy and Harriss, 2002). Systems in the United States, Canada, and Mexico are in place for handling many of these individual data streams (e.g., remote sensing data, forest inventory data), and the NACP data and information management system should build on these existing systems to meet the needs of NACP.



Source: <http://www.fluxnet.ornl.gov/fluxnet/fluxpictures.cfm>

The workshop also specifically recommended that the data management system devote special attention to incorporate socio-economic data into the system (census data, economic profiles, zoning/political boundaries, resource consumption, data mining of social-biophysical data sets to relate carbon dynamics to land use and energy use). Human dimensions of processes controlling carbon budgets are central to NACP, including energy demand modeling, agricultural and natural resource economics, engineering, demographics, land-use patterns, economic valuation, development patterns, and probably much more. NACP requires integration of such data to understand and project these aspects of carbon management into the future.

The workshop also recommended that data products of specific use to decision-support activities be included in the planning for NACP. Identification of these decision-support data products will require input from the end user

community (resource managers, decision-makers, policy makers). How NACP will address decision support is currently a gap in the program and so should be addressed by the NACP SSG as a separate, high-priority issue.

A November 2004 survey of NACP investigators identified data products, as well as other data management functions, that are available or should be made available to study the carbon cycle in North America. Formats for those data products that are anticipated to be used by a broad range of NACP investigators should be identified to ensure ease of use and ready assimilation for analysis and modeling. The survey results are posted on the NACP Data Planning Workshop Web site:

<http://www.nacarbon.org.nacp/dm.html>

The workshop participants recommended that the SSG should resurvey the NACP community to obtain input on the data they are going to need, what the data will be used for, the data quality objectives, and optimum formats and methods of delivery. This information will be used to populate the central NACP clearinghouse with metadata.

The participants suggested that a matrix of observation types vs research themes be used to organize the data requirements and to communicate needs between researchers and data providers. The research themes were identified as inversion, inventory (budget), biogeochemical model, and process models; the observations were atmospheric transport (in three dimensions), surface meteorology, atmospheric constituents, and land parameters (socioeconomic level, vegetation, etc.), flux measurements, carbon stocks, FIA, emissions measurements, etc.

New data assimilation and data fusion methods for analysis of the carbon cycle on a continental scale will generate large volumes of fine temporal and spatial resolution data. The SSG needs to evaluate who will perform these new analyses (e.g., NACP or individual modeling groups) and where the large volume of data produced by these methods will be posted. For some data products with limited demand (e.g., custom input data for a specific model), it may be more appropriate for individual research groups to prepare the data

3. The SSG needs to convene a subcommittee to further clarify the requirements and options for the NACP Data Management System, based on the workshop discussions (near-term action).

The workshop participants discussed a number of design features and criteria that need to be included in the data management system. These features and criteria are listed here:

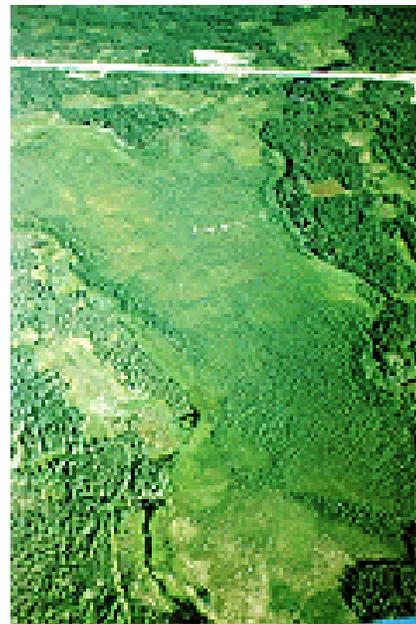
- ◆ Document system requirements needed and have NACP investigator community review documents before building system.
- ◆ Assumptions in the data and data processing need to be made explicit for data users.
- ◆ Four types of data will be handled by the NACP Data Management System: Raster up to 4D, Vector, Point, Time series, Surveys (social science).
- ◆ Need complete and clear metadata. Metadata assembly is time-consuming, but it is the key to enabling secondary reuse of data.
- ◆ Documents that describe field and lab processing, QA/QC techniques and standards are critical components of the metadata for NACP data products.
- ◆ The data system should incorporate version control of data, so that users readily know which version they are using and whether the data products have been updated. There is a need to preserve old versions while including improved datasets (e.g., gap filled data or reprojected data). The CarboEurope project, for example, uses a QA versioning system that allows users to know the limitations of the data.
- ◆ The data system organization should allow both interactive and automated (machine to machine query and transfer mechanism) access to data holdings.
- ◆ Protocols for data interchange formats and processing services will need to be agreed upon and adhered to.
- ◆ The NACP data system should include some core data processing functionality in addition to the centralized clearinghouse / indexing capability. Data processing services of greatest common need (i.e. there are obstacles to the ready use of data/products) should be identified and prioritized, with priority given

to currently funded NACP projects. These services include the following:

- GIS, spatial/temporal subsetting, and format conversion capability
 - Support for real-time data ingest, processing, and distribution
 - Quantitative support for synthesis activities (cross-discipline translator?)
 - Tools for scaling from intensively studied sites to regions to North America to the Globe
 - Dedicated staff with expertise in these areas.
- ◆ If centralized GIS services are needed, NACP should evaluate existing services at data centers, many of which have expert staff who can do some of required reformatting/GIS work cost effectively and with high quality
 - ◆ Need to create essential user tools; avoid the distraction of supertools or toolboxes that do not support users NACP-wide.
 - ◆ Enable subscription services to notify investigators when data, products, or services are available
 - ◆ Incorporate open source collaboration principles in system development efforts (portal design, data filters, format conversion, Web mapping services, cross-platform compatibility; Live Access Servers and OPeNDAP were mentioned as examples)
 - ◆ NACP should adopt open standards for data formats that optimize the use of existing tool sets for common data processing operations like subsetting and aggregation (e.g., NetCDF, Live Access Servers).
 - ◆ For data products that will be used widely within the program, NACP should identify data formats to ensure ease of use and ready assimilation for analysis and modeling.
 - ◆ A standard set of projection and grid registration parameters should be adopted for continental-scale analyses and data sets, with the possibility of multiple parameter sets for multiple spatial resolutions.
 - ◆ NACP should begin synthesis activities as early as feasible, certainly before all the data have been collected. Such syntheses activities guide and greatly enhance future data collection and data management activities.

- ◆ NACP should assemble and distribute major models developed by and used within the program, along with model parameter values and input and output data. For some activities, the model output will be used for subsequent modeling and assessment.
- ◆ Measures of success for the Data Management System need to be defined. NACP should consider some indices of data use such as data downloads from file transfer protocol or Web pages, data queries, numbers of distinct users (user registration).
- ◆ Plans should be made for the long-term archival and distribution of key NACP data products, including value-added products generated by the project.

In addition to these features, the workshop participants recommend that NACP develop a common learning environment that describes data use scenarios by discipline, for example, a primer or description of methods of how data were assembled and ingested into a specific inversion model involving atmospheric transport. The workshop envisioned these as helpful primers or succinct documentation that describes how the data were used in the past, the problems with the data, how those problems were dealt with, etc. These primers are distinct from the very detailed documentation that generally accompanies the data set.



Source: http://daac.ornl.gov/BOREAS/boreas_photos_pages/BOREAS_PHOTOS.htm

The workshop recommends that NACP build the data system around thematic nodes (e.g., top down inversion modeling), each with a group of scientific thematic experts who can oversee / assist with developing the data products. The themes are organizing portals (Web-based) that guide users and providers and assist in bringing the maximum experience to data management.

4. NACP should establish a centralized Web-based metadata clearinghouse that contains an index of metadata, data, and services with links to distributed data (near-term action).

Currently funded NACP investigators urgently require this clearinghouse for the data that have been and

will be collected, especially those collected during intensive campaigns [e.g., the upcoming (2005 – 2006) Mid-Continent Intensive Campaign]. Because this recommendation is time critical, existing portals and metadata editors should be examined, rather than developing a new system. The Web portal should have several types of data query / discovery services ranging from data catalog entries (structured database) to free text metadata search. To ensure interoperability, the clearinghouse should be compliant with ISO and Open Geospatial Consortium (OGC) open-standards. The access to needed products from other sources as well as NACP-specific products should be seamless.

5. The CCIWG, in conjunction with the SSG, needs to establish a process for identifying and prioritizing the production of value-added products relevant to NACP objectives.

The CCIWG, with assistance from the SSG, should perform a cost / benefit analysis to determine whether proposed value-added products meet the following criteria:

- ◆ product required to meet NACP objectives;
- ◆ products needed by multiple users that are not currently funded for development;
- ◆ products that are essential or would enhance analyses and that are not already being generated by funded research teams or data centers; and
- ◆ compilation of value-added products does not involve new research effort, but rather only implementation of existing, accepted (published) methods.

“Many of the required data streams exist today, but are not produced consistently at the time/space resolution needed, and the data are not assembled into an integrated set for data fusion. Because of the diversity of data and multiple temporal and spatial scales, it will be a significant challenge to make these data available for data assimilation activities and for public use. Hence, enabling activities are needed in this area.”

—*NACP Report* (Wofsy and Harriss, 2002), p. 25

Workshop participants identified the following high-priority value-added products that meet the above criteria.

- ◆ Continental elevation and elevation-derivatives at multiple resolutions (1 km and 90 m)
- ◆ Continental gridded surface weather products (1 km, daily, through present with annual updates)
- ◆ Continental land-use and disturbance history data sets (50-100 years)
- ◆ Landsat data analyzed to include land cover, disturbance, and LAI (this may be more of a research product)
- ◆ Soil carbon and nitrogen from STATSGO, SSURGO, other field data sets (1 km, 5-year updates)
- ◆ Biogenic and anthropogenic greenhouse gas emissions (CO₂, CH₄, CO)
- ◆ Forest and natural resource inventories
- ◆ Historical data that need to be digitized
- ◆ Gridded annual crop type data

Data Policy

6. The SSG should develop a data policy regarding sharing of data collected under the auspices of the NACP, access to NACP data by the broader scientific community and by the public, and expectations for short- and long-term data archive. The CCIWG should work with the SSG to develop effective means

for implementing this data policy (near-term action).

Managing and integrating data for NACP requires an overarching data policy that provides open access to environmental data for North America in a timely manner. The policy needs to be established and approved by the United States, Canada, and Mexico.

The NACP Science Implementation Strategy Plan outlines additional key elements that should be treated in the NACP Data Policy:

- ◆ Definition of the data that falls within the purview of the NACP data policy (e.g., primary observations collected by NACP investigators; monitoring data compiled by U.S., Canadian, and Mexican agencies; site characterization, remotely sensed data, and ancillary data required by NACP);
- ◆ Responsibility of NACP-participating agencies and investigators to release data to the NACP user community in a timely manner (e.g., define the period of restricted access, if any); may want to invoke a specific lag between data collection and access;
- ◆ Timely release of data and documentation to the public (e.g. within 0, 1, or 2 years of collection);
- ◆ Timely documentation of data products;
- ◆ Protection of the intellectual property rights of data originators;
- ◆ Protection of the rights of students;
- ◆ Acknowledgement of NACP and its sponsors;
- ◆ Establishment of a process and timeline for archiving key NACP data;
- ◆ Resolution of conflicts over data and the data policy; and
- ◆ Approaches for effective implementation.

The agencies involved in NACP should formulate a strategy for archival of data and products developed by NACP project activities. NACP data products, including value-added products generated by the program, need to be

archived when the data sets are finalized or at the completion of NACP. The workshop participants felt that a data archive plan was critical because of the distributed nature of the data management system with individual investigators holding active data products. As investigators move on to other projects, there is a real potential for the data products to be unavailable to future users. A data archive plan developed early in NACP will prevent such loss of data.

Many data products used for NACP are currently being archived by agency or national data centers, and NACP should not duplicate those

efforts. CCIWG should identify agency roles and responsibilities, commitment, and the issues/concerns of international collaborators associated with

long-term data archival. The CCIWG needs to contact those agencies with long-term archive responsibilities to inquire whether they would be interested and supportive of archiving NACP-specific data products.

Quality Assurance of NACP Data and Data Products

7. The SSG needs to establish and implement protocols for QA, including establishing definitions and standards for data QA and QC, uncertainties, error analyses, and documenting the quality of the data products.

The protocol should consider the following aspects of QA:

- ◆ identify what measures of uncertainty and bias should be reported with data and data products;
- ◆ adopt guidelines for evaluating and expressing uncertainty of data, using a tiered approach to allow differing levels of use;
- ◆ establish a protocol for including QA/QC data with measurement data submissions;
- ◆ produce QA/QC information in a user-friendly format;
- ◆ establish protocols for ensuring the integrity of data products;

“All data will be made generally available immediately in preliminary form at a single website. Rapid comparison of different data sets is essential for maintaining quality control. Data will be ‘flagged’ and corrections made as the analysis proceeds.”

—*NACP Report* (Wofsy and Harriss, 2002), p. 39

- ◆ establish a mechanism for documenting the QA/QC status of all data sets so that users know the limitations of data for specific applications; and
- ◆ establish a mechanism for documenting known data problems.

The SSG must define a process to solicit and incorporate coordinated feedback on data quality between data users and data providers. The workshop participants noted that problems with the quality of data products are discovered as data are used by the producers and by others, especially during synthesis activities. Even though these quality issues may be discovered by others, the ultimate responsibility for assuring the quality of data resides with the data producer.

The SSG should work with the NACP Office to implement and manage these protocols.

8. NACP should publish peer-reviewed data reports for documenting primary NACP data sets.

NACP data reports would describe the data, the objectives for data collection, how the data were compiled, and the quality of the products. For example, these data reports are a necessary element of compliance with the Information Quality Act for using data to derive policy.

Resources Required

9. The CCIWG should investigate innovative and efficient ways of engaging existing data centers in the data management activities of NACP.

Based on the data requirements of NACP identified in Recommendation No. 2 and No. 3, substantial resources need to be brought to bear on NACP data management functions and services. Because resources for NACP data management will be limited, many critical data management functions will need to be performed by existing agency data centers or science teams. The workshop participants recommend that data centers that deal with measurements of import to NACP (e.g., those dealing with atmospheric concentration measurements, flux measurements, remote sensing products, weather reanalysis, fossil fuel emission, and carbon inventories) and science teams that are responsible for key data products may be able to provide significant and specific

data support to NACP through negotiated realignment of their activities.

10. The NACP participating agencies need to balance the NACP data requirements that result from numbers 1–5 above with resources available (“right-size” the data management system).

Because the Data Management System will most likely be funded with reprogrammed base funding, NACP needs to balance data management requirements with funding resources available (“right-size” the data management system). These funding resources will be above and beyond using the existing data management infrastructure identified in Recommendation No. 9.

As the program matures, NACP synthesis activities may require a central data system (i.e., a VEMAP-type data activity).

11. NACP participating agencies should identify resources to design and develop an NACP Web portal and metadata editor (near-term action)

The workshop participants encourage the NACP funding agencies to identify resources for the implementation of the NACP-central Web metadata portal and a metadata editor. The workshop participants recommended that, to the greatest extent possible, NACP should leverage existing capabilities and resources (i.e. existing tools) and that the design of the Web portal should include Web services standards. A number of possible tools were discussed, including THREDDS, Mercury, and GCMD.

12. NACP participating agencies should fund dedicated staff to work with investigators on data and metadata issues (near-term action).

NACP requires staff to work with agencies and investigators to facilitate cataloging of data and to review metadata. This activity should start as soon as feasible. The workshop participants envision that this staff will be responsible for day-to-day data management activities.

13. The NACP participating agencies need to ensure that NACP PIs allocate sufficient resources to support their project’s data management activities.

Individual projects should allocate resources to meet their specific data management needs. The individual investigators are responsible for performing data management activities for the data generated by their projects: assembly, document data collection methods, prepare metadata, describe QA/QC information and quantified measures of uncertainty, and prepare data for inclusion the NACP Data Management System. The NACP Data Management System will focus primarily on program-wide data management activities.

The workshop participants recognize that the NACP participating agencies cannot place new requirements on projects that are under way, but encourage the agencies to ensure new solicitations and future projects have requirements for project-level data management functions.

“NACP agencies and scientists will work with operational centers (NOAA NCEP, NASA DAO, and ECMWF) to support archival of full meteorological analyses on hourly time steps, rather than the aggregated archives currently provided, and to improve accuracy of the assimilated projects.”

—*NACP Science Implementation Strategy*, 2004, p. 38

“A prototype database of historical information should be developed in the preliminary phase, including the current state of land surface (cover, age since disturbance, management, biomass, soil carbon stocks).”

—*NACP Report* (Wofsy and Harriss 2002)

Establish Coordination between Agencies and Data Centers

14. The CCIWG needs to establish data coordinating agreements [Memorandums of Understanding (MOUs)] with U.S. agencies, Mexico, Canada, intergovernmental agencies, and international scientific bodies where necessary and feasible.

Unprecedented levels of cooperation across current U.S., Canadian, and Mexican data management institutions and programs will be required to achieve the goals of NACP. Data coordinating agreements will help to ensure effective interfaces between NACP and the data

centers. NACP should also seek to leverage resources and services from agency data centers to the greatest extent possible to take full advantage of existing capabilities and data streams.

How to Exert Oversight and Management of the NACP Data Management Program

15. The CCIWG needs to establish a Data Management Working Group comprised of data producers, data users, and data system developers to provide coordination and

integration of data management with research activities, with a focus on addressing NACP science questions (near-term action).

The CCIWG needs to define a charter for the Data

Management Working Group, which will facilitate data management, interface with data providers/centers, and PIs. The Workshop participants recommend that the Data Management Working Group reports directly to the CCIWG and provides copies of their assessment reports to the SSG.

Close coordination among data managers, those making the measurements, modelers, and other data users is critical. NACP requires real integration and dialogue between the research teams and the data systems to both define and realize data product requirements.

16. NACP funding agencies should develop the means to make the NACP data management guidelines and policies as effective as possible.

Success of the data management system is largely contingent upon collective adherence to data policy, guidelines, and recommendations. The CCIWG should evaluate how to make the policies and guidelines as effective as possible, as well as use innovative methods to encourage adherence to the policies. The CCIWG should communicate to NACP-funded investigators the data management policy and expectations, including any repercussions of not complying with the policy.

17. The CCIWG should promote the coordination of data management and data synthesis through annual or semiannual modeling / analysis workshops for regional intensive campaigns or North America-wide studies.

Close coordination with the users of the data system, including clear identification of the required data and the data management functions, is a necessity. To facilitate this ongoing coordination, the CCIWG should plan and convene periodic data integration and synthesis workshops to assess the information collected to date and consider further requirements for observations or experiments.

Integrating Human Dimensions into NACP

During the course of the workshop, participants recognized that social sciences had not been sufficiently incorporated into NACP.

Although this topic was not in the purview of the data management

planning

workshop, the workshop offers

the

recommendation

that the CCIWG

needs to include

full consideration

of human

dimensions of the

carbon cycle, by

incorporating

social sciences

into the research

objectives for

NACP and by

forming a working group for the stakeholder

community. In addition, the workshop

recommended that NACP funding agencies should

develop research solicitations to enhance human dimension engagement on carbon science issues.

Intellectually, human dimensions of processes controlling carbon budgets are central to NACP

Question 2

(source/sink

attribution). These

include energy

demand modeling,

agricultural and

natural resource

economics,

engineering,

demographics, land-

use patterns,

economic valuation,

development

patterns, and

probably much

more. NACP

Question 3

(prediction) requires credible attempts to

understand and project these human dimension

aspects of carbon management into the future.



Source: <http://caplter.asu.edu/images/CAPLTER/genCityscape/>



References

Denning, A.S. et al., 2005. Science Implementation Strategy for the North American Carbon Program, Available on-line at <http://www.nacarbon.org/nacp/documents.html> . Climate Change Science Program, Washington, D.C.

Wofsy, S.C. and R.C. Harriss. 2002. The North American Carbon Program Plan (NACP). A Report of the Committee of the U.S. Carbon Cycle Science Steering Group. Available on-line at <http://www.nacarbon.org/nacp/documents.html> . Climate Change Science Program, Washington, D.C.



Source: <http://www.fluxnet.ornl.gov/fluxnet/fluxpictures.cfm>



Appendix A

Final Draft

Charge to NACP Data Management Workshop

The Federal science agencies comprising the Carbon Cycle Interagency Work Group (CCIWG) are overseeing an ambitious scientific program to close the carbon budget for North America. This program, entitled the North American Carbon Program (NACP), addresses several basic questions:

1. What is the carbon balance of North America and how is the balance changing over time? What are the sources and sinks, and the geographic patterns of carbon fluxes?
2. What factors control the sources and sinks, and how do they change with time?
3. Are there potential "surprises", where sources could increase or sinks disappear?
4. How can we enhance and manage long-lived carbon sinks to "sequester" carbon?

Federal agencies currently collect large amounts of the data needed for the NACP effort. A partial list of existing projects and data sources currently managed by the CCIWG agencies is shown in Figure 1.

In addition to the existing data sources, large new data streams will be initiated during the NACP that will range from fixed sites on the continent and ocean margins to ones collected over wide geographic areas by ships, satellites, or aircraft. Some of the data to be collected will be site specific and collected as a part of process investigations over relatively short periods of time, while other data streams will be continuous. Investigators funded through federal agencies will generate significant amounts of data. As outlined in the NACP plan a 20-year retrospective analysis will be performed requiring "mining" of historical datasets. An additional complexity is that in order to achieve the goal of closing the carbon budget for North America, carbon data from both Canada and Mexico will need to be acquired from their federal science agencies.

At the NACP Principal Investigators Meeting in May 2003 where the draft NACP Implementation Plan was reviewed by more than 200 scientists involved, or interested in the NACP,

the lack of a clear plan for collecting, integrating, quality assuring, and archiving the massive amounts of data needed for the program was clearly outlined as a deficiency by a number of the breakout groups.

The data system that results from the workshop should be flexible, because requirements have not been fully established, and even if they were, the system needs to evolve to meet changing research and technologies. At this workshop, we envision that a comprehensive roadmap for a data ingestion, data handling, and data synthesis for the NACP will be produced. A vision of a comprehensive data management system encompassing the needs of observationalists and modelers should address the following topics:

Data Management Strategy

- ◆ Providing central access to NACP data
- ◆ Feasibility of using existing DM infrastructure (i.e., Mercury, data centers)
- ◆ Design, development, implementation strategy

Data Accumulation

- ◆ Formatting
- ◆ Standards e.g., UTC, identifying missing data, providing uncertainty with data, data quality
- ◆ Automated process for providing data or "link" to central NACP data distribution point
- ◆ Documentation e.g., Calibration history, Comparability history

Data Distribution and Access

- ◆ Maintenance of project information; schedules of activities; e-mail list servers
- ◆ DB manipulation tools
- ◆ Registry of data and Web sites (implementation of data policy)

NACP-Wide QA/QC

- ◆ Protocol for establishing levels of comparability for data sets derived using independent methods
- ◆ A review process for the status of data and data problems

Value-Added Products

- ◆ Compilation of data for NACP-wide use
- ◆ Enhanced data products

Note: The USGCRP Data Policy will be provided to workshop attendees as well as a summary of NACP data needs identified in the NACP Implementation Plan.

Additional Guidance

The deliberations of the workshop should be presented in a report that includes recommendations to the CCIWG about the data management system design; the resources required; interfaces between agencies and data centers; and how to exert oversight and management of the NACP Data Management Program. The attendees should keep in mind that the NACP data management efforts will most likely be funded from base funding or re-programmed funds. Therefore it is important to consider existing infrastructure wherever considering options.



Critical Data Dependencies (U.S. Agencies)

Figure 1

USDA

- ◆ Forest and soil inventories
- ◆ Agricultural, forest, and range management
- ◆ Carbon sequestration
- ◆ Land use

NOAA

- ◆ Meteorological observations
- ◆ Ocean surface temperature and land cover observations
- ◆ Atmospheric CO₂ observations
- ◆ Weather models (NCEP)
- ◆ Air-Sea CO₂ exchange studies
- ◆ Integrated carbon modeling
- ◆ Ship-based ocean CO₂ surveys

DOE

- ◆ Fossil fuel emissions
- ◆ AmeriFlux
- ◆ FACE and other CO₂ experiments
- ◆ Carbon databases (CDIAC)
- ◆ Carbon modeling and carbon sequestration
- ◆ ARM and ARM carbon projects

USGS

- ◆ Landsat data and data products
- ◆ Topography and land cover maps
- ◆ Stream gauge network
- ◆ Hydrography

NASA

- ◆ Remote sensing: satellite time series (Landsat, SeaWiFS and EOS); expt. airborne sensors
- ◆ Remote sensing research
- ◆ Field campaigns— LBA, BOREAS
- ◆ Ocean, land, atmosphere, and coupled carbon-climate modeling;
- ◆ ESTO, Data sets, and DISS

NSF

- ◆ Earth science research
- ◆ Ocean field campaigns
- ◆ Process studies
- ◆ NCAR, NCEAS, LTER
- ◆ Cyber Infrastructure Initiative



Appendix B

NACP Data Management Planning Workshop
January 25 – 27, 2005
New Orleans, LA

Agenda

Tuesday, January 25

7:30 Breakfast

8:00 – 12:15

8:00 Welcome/Workshop Objectives/Logistics Bob Cook
Tribute to Dave Shultz Diane Wickland

PLENARY: TOPICAL PRESENTATIONS

8:15 Role of the NACP in the Climate Change Science Program Diane Wickland
8:45 NACP Goals and Implementation Strategy Scott Denning
9:15 NACP Data Management Framework Bob Cook
10:00 Break

10:30 Vegetation/Ecosystem Modeling and Analysis Project (VEMAP) Tony King
11:15 Data Management in CarboEurope Reiner Krause
12:15 Lunch

1:00– 5:30

PLENARY

1:00 Session assignments and goals Peter Thornton

BREAKOUT SESSIONS

1:30-4:00 Breakout sessions on Cross-Cutting Issues

- ◆ Breakout Group 1 – Data Accumulation (Jeff Morisette and Tom Reinsch)
- ◆ Breakout Group 2 – QA/QC for NACP Data Products (Jeff Goebel and Linda Heath)
- ◆ Breakout Group 3 – Data Distribution and Access (John Dwyer and Joe Coughlan)
- ◆ Breakout Group 4 – Value Added Products (Tom Loveland and Dennis Ojima)

3:00 Break

PLENARY

4:00–5:30 Breakout session reports to workshop: Cross-cutting issues
4:00 Data Accumulation Thomas Reinsch
4:15 QA/QC for NACP Data Products Linda Heath
4:30 Data Distribution and Access Joe Coughlan
4:45 Value Added Products Dennis Ojima
5:00 Discussion

6:00 – 8:00

EVENING SESSION

6:00–8:00 Poster Session and Heavy hors d'oeuvres

Wednesday, January 26

8:00 Breakfast

8:30 – 12:30

PLENARY

8:30 Update

BREAKOUT SESSIONS

8:45 Continuation of breakout sessions

10:30–11:00 Break

PLENARY

11:00 Breakout session reports to workshop

11:00 Data Accumulation

11:15 QA/QC for NACP Data Products

11:30 Data Distribution and Access

11:45 Value Added Products

12:00 Discussion

12:30 Lunch

Thomas Reinsch

Linda Heath

Joe Coughlan

Dennis Ojima

1:15 – 5:00

PLENARY

1:15 Plenary

BREAKOUT SESSIONS

1:30 Continuation of breakout sessions

3:00 Break

PLENARY

4:30 General Discussion

Dinner (on your own)

Thursday, January 27

8:00 Breakfast

8:30 – 12:00

PLENARY

8:30	Breakout session reports to workshop and discussion	
8:30	Data Accumulation	Thomas Reinsch
9:00	QA/QC for NACP Data Products	Linda Heath
9:30	Data Distribution and Access	John Dwyer
10:00	Value Added Products	Dennis Ojima
10:30	Break	
11:00	Discussion of session reports	Bob Cook
	Next steps and action plan	Peter Thornton
11:30	NACP and CCIWG response	Scott Denning
		Diane Wickland
12:00	Adjourn	

Workshop Deliverable

The workshop participants will prepare a report that includes recommendations to the CCIWG on the data management system design; identify near-term activities (pilot / prototype) as well as long-term activities; the resources required; interfaces between agencies and data centers; and how to exert oversight and management of the NACP data management program.



Appendix C

Breakout Groups NACP Data Management Planning Workshop January 25-27, 2004

Objectives and Charge to Breakout Groups

- ◆ Desired outcome: a comprehensive vision for NACP Data Management System
 - Clarify the system requirements
 - Produce a strategy for design, development, and implementation that addresses available options and resource requirements
- ◆ Initial design criteria:
 - Centralized access to NACP data
 - Make effective use of existing data management infrastructure
 - Plan for broad spectrum of data types
 - System should be “flexible”

Breakout Group Questions

Cross-Cutting Issues for each Breakout Group to Consider

Data Framework

1. Overall data management objectives
2. High-priority data products
3. Key elements of a data policy
4. Centralized vs distributed data system
5. Acquiring data and documentation from investigators and transferring to an appropriate archive

Data Accumulation Breakout Group

Leader: Jeff Morisette (NASA GSFC)

Rapporteur: Thomas Reinsch (USDA NRCS)

Steering Committee: Sharon Waltman (USDA NRCS)

1. “Where” does NACP data accumulation occur? Is it a central facility, or is it a distributive network?
2. How are the data stores “classified” or “organized”? By scales of time and space? Scale of model?
3. What data formats will be used? One format for input parameters (measurements and observations) and an alternative format for model output results?
4. What are the data content quality standards used for the NACP data?
5. What is the metadata content? Federal Geographic Data Committee (FGDC) standards for public data versus internal standards (NetCDF) for internal users?
6. What is the lifetime of the data? Duration of NACP or longer time archive?

Quality Control / Quality Assurance Breakout Group

Leader: Jeff Goebel (USDA NRCS)

Rapporteur: Linda Heath (USDA FS)

Steering Committee: Ken Masarie (NOAA CMDL) and Scott Denning (Colorado State University)

Can we...

1. identify what measures of uncertainty and bias should be reported with data and data products?
2. adopt existing guidelines for evaluating and expressing uncertainty of data e.g., American National Standards Institute (ANSI/NCSL)?
3. establish a protocol for including QA/QC data with measurement data submissions?
4. produce QA/QC information in a user-friendly (useable) format?
5. establish a mechanism for documenting/summarizing the QA/QC status of all data sets?
6. establish a mechanism for documenting/summarizing known data problems?
7. identify who is responsible for performing which QA procedures?

Data Distribution and Access

Leader: John Dwyer (LP DAAC)

Rapporteur: Joe Coughlan (NASA Ames)

Steering Committee: Rich Birdsey (USDA FS) and Dave Glover (WHOI)

1. Are the data management center(s) of the NACP to act as an archive, distribution portal, or both?
2. Should the communication protocols be established in advance? Once the communication protocols are established the modes of access are known, and software for manipulation can be developed.
3. NACP needs to decide, will its database(s) be open access, semi-open access, or restricted access?
4. Will/should the various data management nodes have advisory committee of users?
5. Are there easily identified, high-profile databases needed by NACP scientists, but not produced by NACP scientists?

Value-Added Data Products

Leader: Tom Loveland (USGS EROS Data Center)

Rapporteur: Dennis Ojima (Colorado State University)

Steering Committee: Peter Thornton (NCAR) and Bev Law (OSU)

1. What would be the most efficient way to organize the effort required to generate value-added products that fit the scope? One possibility is to focus these efforts at an NACP Data Center. Another possibility is to identify existing research teams or data centers to handle individual value added products, as appropriate.
2. For value-added products that require significant scientific effort or guidance, where will this guidance come from and how will it be organized? (science teams, community involvement in planning.)
3. Other value-added products might derive more from data manipulations than new science efforts. What sort of general capabilities will be required to handle these products? Should these efforts be centralized at an NACP data center?
4. What level of computational resource and on-line storage will be required to handle any value-added products, and what is the most efficient way to obtain and organize these resources?
5. Are there any archiving, distribution, or access issues specific to value-added products that should be addressed in our plenary Data Management Framework discussions?

6. Identify value-added products in several categories:
 - a. ecosystem processes
 - b. atmospheric processes
 - c. ocean processes
 - d. remote sensing products
 - e. other categories?

Workshop Report

The workshop participants will prepare a report that includes recommendations to the CCIWG on data management system design

- ◆ identify near-term activities (pilot / prototype) as well as long-term activities
- ◆ resources required
- ◆ interfaces between agencies and data centers
- ◆ elements of an NACP Data Policy
- ◆ how to exert oversight and management of the NACP Data Management Program



Appendix D

Posters Presented at the Workshop

Name	Poster Title	Affiliation
Bliss, Norman	Sensitivity of Soil Carbon Stock Estimates to Soil Spatial Patterns	USGS EROS, SAIC
Bliss, Norman	Soil Organic Carbon Stocks for the Conterminous United States	USGS EROS
Cook, R. B.	ASCII Subsets of MODIS Land Products for Selected Sites	ORNL
de Jon, B.H.J	Land-use Change and Related Carbon Emissions in Mexico	ECOSUR, Mexico
Dwyer, John	MODIS Land Products from the LP DAAC at EROS	USGS
Dwyer, John	MODIS Data Tools Available Through the Land Processes DAAC	USGS
Franken, Sandra	Elevation Derivatives for National Applications	USGS
Heinsch, F.A.	Using Biome-BGC and MODIS to Estimate Production in Annual Crops - A Study in Nebraska	University of Montana

Name	Poster Title	Affiliation
Hooper, Rick	Designing Hydrologic Observatories as a Community Resource	CUAHSI
Hrynkiw, Charmaine	Fluxnet-Canada Data Information System	Meteorological Service of Canada
Krause, Reiner	Design and Development of the CarboEurope-IP Central Database	Max-Planck-Institute for Biogeochemistry
Masarie, K.A.	Estimating Uncertainty in Atmospheric Trace Gas Measurements	NOAA CMDL
Masarie, Ken	The GLOBALVIEW-CO ₂ Data Product	NOAA CMDL
Mu, Qiaozhen	Water Stress Effects on Primary Production in A Biogeochemical Model and a Radiation Use Efficiency Model in USA during 1982-1997	University of Montana
Oakins, Alana J.	A Framework for Continuous Monitoring of the Biosphere at Multiple Scales	University of Montana
Ojima, Dennis	Looking for carbon in all the wrong places: Multi-scale carbon measurements in the Rocky Mountains - ACME 04	Colorado State University
Ordonez, J.A.B.	Evolution of Carbon Stocks and Emissions from Land Use Change in the Purepecha Region in Central Mexico	Laboratory of Bioenergy

Name	Poster Title	Affiliation
Parkin, T. B.	Autocorrelation to Fill Gaps in Soil Respiration Measurements	USDA-ARS
Porter, John	Using Ecological Metadata Language (EML) in the U.S. Long-Term Ecological Research Network	University of Virginia
Spinney, Michael	The Forest Carbon OnLine Estimation (COLE) Web Tool	National Council on Air and Stream Improvement
Thornton, Peter	Grid-BGC:Grid-Enabled Terrestrial Carbon Cycle Modeling System	NCAR/University of Colorado
Thornton, Peter	Daymet: Gridded Daily Surface Weather for Biogeochemistry Modeling	NCAR/University of Colorado
Rhyne, Tim	Technologies for Enabling Projects	ORNL
Voorhees, L.D.	The ORNL DAAC: A Source for Biogeochemical and Ecological Data	ORNL
Waltman, Sharon	Soil Organic Carbon in North America	USDA/NRCS
Zhao, Maosheng	Sensitivity of MODIS Global Terrestrial Primary Production To The Accuracy of Meteorological Data Sets	NTSG/University of Montana



Appendix E

**NACP Data Management Planning Workshop
25-27 January 2005
New Orleans, LA**

Participant List

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