To advance understanding of the Earth system, describe the consequences of climate change, and evaluate and inform policy on the outcomes of climate change responses.

-CCSI Mission Statement

Climate Change Science Institute Project Portfolio

January 2012

Climate Change
SCIENCE INSTITUTE

This page left intentionally blank.

Table of Contents

This page left intentionally blank.

CCSI Projects Overview

CCSI continues to integrate scientific capabilities between world-class experimental systems, carbon and water cycle observation systems, and Earth system modeling. We have defined four overarching themes that enable leadership to identify where resources, proposal writing, and other efforts should be directed to maintain focus and achieve a critical mass of effort. Our projects are grouped by the primary research theme that they support. However, many of our projects are truly multi-theme, as they draw upon the expertise from more than one research theme, thereby creating the integration which is essential to our success.

The four themes and their respective leads are

Earth System Modeling (James Hack)

Data Integration, Dissemination, and Informatics (Giri Palanisamy)

Terrestrial Ecosystem and Carbon Cycle Science (Peter Thornton)

Impacts, Adaptation, and Vulnerability Science (Ben Preston)

A complete listing and description of CCSI projects can be found on our website: ccsi.ornl.gov. The

funding for our projects has been approximately $100 million annually for both FY10 and FY11. While the majority of CCSI's funding comes from the US Department of Energy Office of Biological and

Environmental Sciences, several projects are funded by a variety of other sponsors, including

US DOE Office of Advanced Scientific Computing Research

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

US Geological Survey

Our partnerships are a critical component in achieving our strategic vision. Through partnerships, we are able to conduct more comprehensive climate change research, seamlessly. Our current partners include:

DOE National Laboratories

Argonne National Laboratory
Brookhaven National Laboratory
Los Alamos National Laboratory
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratory
National Renewable Energy Laboratory

Universities

Boise State University
Texas A&M University
University of Prince Edward Island

Duke University
Florida State University
Johns Hopkins University
Lund University (Sweden)
New York University
Massachusetts Institute of Technology
Purdue University
Rutgers University
UC-Berkeley
UC-Davis
UC-Irvine
University of Alberta (Canada)
University of Illinois – Chicago
University of Michigan
University of Oregon
(Canada)
University of Puerto Rico
University of the Sunshine Coast (Australia)
University of Sydney (Australia)
University of Tennessee
University of Utah
University of Victoria (Canada)

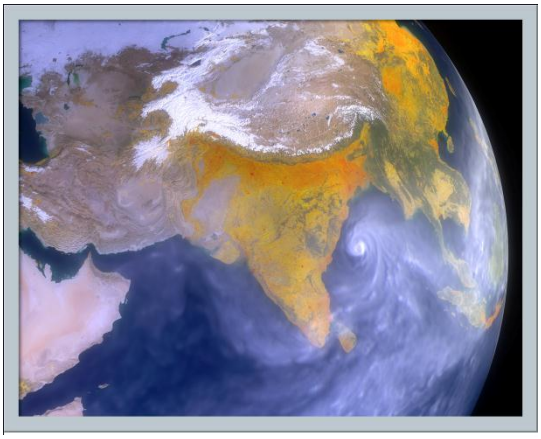
National Agencies

National Aeronautics and Space Administration
National Center for Atmospheric Research
National Oceanic and Atmospheric Administration
National Science Foundation
US Army Cold Regions Research & Engineering Lab
US Department of Agriculture
USDA Forest Service
USDA Land Management and Water Conservation Research
US Global Change Research Program
US Geological Survey

Other Partners

Barrow Arctic Science Consortium DuraSpace.org

Earth System Modeling



Exploiting ORNL and DOE Office of Science competencies in high-performance computing and multi-scale computational science, the Earth System Modeling theme focuses on determining the benefit of exploiting very-high-resolution global models to support the investigation of regional climate phenomena, especially those related to the hydrological cycle. An important function in the development and deployment of an ultra-high-resolution model will be to test the hypothesis that high-resolution models are necessary to simulate non-linear phenomena and interactions on the small scale that have feedbacks on large scale climate behavior, and for the accurate simulation of local to regional scale phenomena. Focuses within the Earth System Modeling theme include:

- Integrated High Resolution Global Climate Modeling
- Climate Extremes
- Parameterization Studies
- Computational Mathematics
- Scalable Algorithm Development

Climate Science for a Sustainable Energy Future (CSSEF)

PRINCIPAL INVESTIGATOR: James J. Hack

PARTICIPATING STAFF: Thomas Baron, Gautam Bisht, Marcia Branstetter, Xiaohui Cui, David Erickson, John Harney, Jitu Kumar, Jaifu Mao, Ross Miller, Richard T. Mills, Daniel Ricciuto, Xiaoying Shi, Galen Shipman, Peter Thornton, Dali Wang, Feiyi Wang, Xiaojuan Yang

PROJECT START DATE: 2011

PROJECT END DATE: TBD

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, National Center for Atmospheric Research

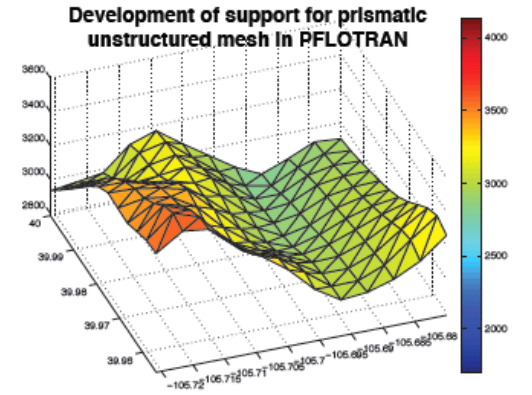
PROJECT DESCRIPTION

The Climate Science for a Sustainable Energy Future (CSSEF) is a collaborative project among Oak Ridge and other national laboratories to transform the climate model development and testing process and thereby accelerate the development of the Community Earth System Model's sixth-generation version, CESM3. Four research themes are addressed in the project: 1) a focused effort for converting observational data sets into specialized, multi-variable data sets for model testing and improvement, 2) development of testbeds in which model components and sub-models can be rapidly prototyped and evaluated, 3) research to enhance numerical methods and computational science research focused on enabling climate models that use future computing architectures, and 4) research to enhance efforts in uncertainty quantification for climate model simulations and predictions.

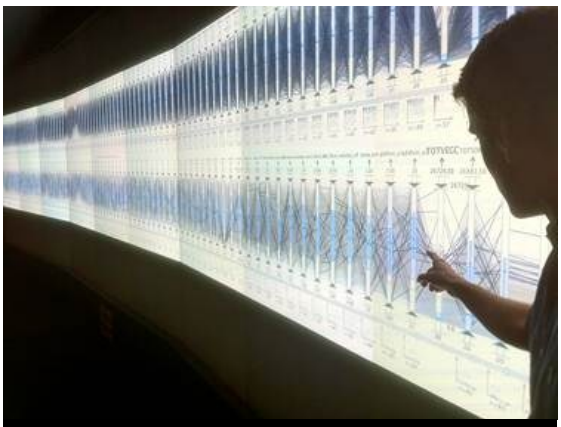
These four themes are mutually reinforcing and tightly coupled around three overarching research directions: 1) the development, implementation, and testing of variable-resolution methodologies that enable computationally efficient simulation of the climate system at regional scales, 2) improvement of the representation of the hydrological cycle and quantification of the sources of certainty in its simulation, and 3) the reduction and quantification of uncertainties in carbon cycle and other biogeochemical feedbacks in the terrestrial ecosystem.

SIGNIFICANCE

This project will accelerate the incorporation of new knowledge, including process data and observations, into climate models and will develop new methods for rapid validation of improved models. CSSEF exploits computing at the level of many tens of petaflops in climate models.

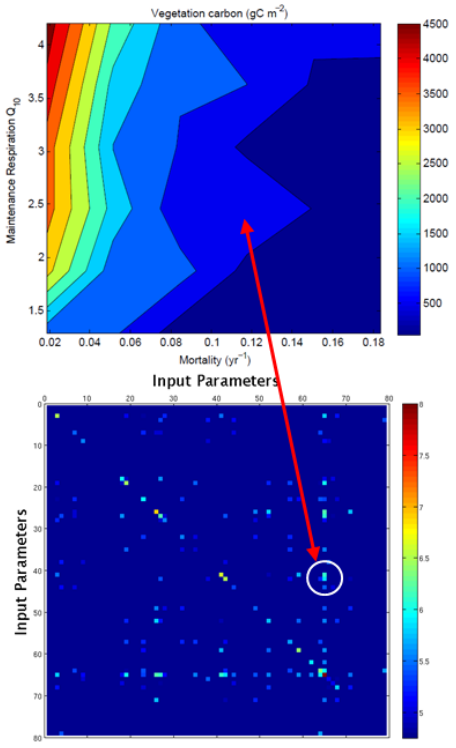


Improved surface and subsurface flow modeling requires new modeling grids



Real-time dynamic visualization of multi-parameter model sensitivity output, using the EDEN framework on EVEREST

Climate Science for a Sustainable Energy Future (CSSEF)



(Upper Image) Influence of two model parameters (temperature response and plant mortality) on model output (plant carbon).

(Lower Image) Quantifying the effects of many parameters (80 shown here) on model output. Circle indicates parameter pair expanded in top panel.

Climate model development is a mature and ongoing enterprise that has numerous and diverse participants, ranging from graduate students in academic programs to senior leaders in dedicated climate research laboratories. The CSSEF will have its maximum impact through integration with the core long-term development of the Community Earth System Model (CESM) project. The CESM, formerly the Community Climate System Model, is a long-standing collaborative and internationally recognized effort that has involved the National Center for Atmospheric Research (NCAR), several DOE national laboratories and numerous academic institutions for over 15 years. The collaboration has produced four generations of State-of-the-Science global climate models, including the most recent, CESM1. While much of the community effort is now dedicated to application of CESM1 and the development of CESM2, CSSEF will focus on the long-term development of CESM3, which is consistent with plans described in the CESM Science Plan (Appendix 2). The paradigm of multiple, parallel development paths to build successive generations of predictive models explicitly acknowledges that aspects of model development, particularly those requiring significant new research tasks, take longer time between model releases. While aspects of development require 10 to 15 years, a new major new version of CESM is released every 5 to 6 years.

CSSEF will undertake several unique and potentially transformative research directions, including

- The capability to thoroughly test and understand the uncertainties in the overall model and its components as they are being developed;
- Major scientific advances in the components that will achieve greater fidelity in modeling feedbacks in the climate system;
- Development of model evaluation procedures that allow the rapid ingest of observational data for model and component evaluation;
- Flexible dynamical cores that enable fine-scale simulations; and
- Early adaptation of the model algorithms and code to the next generation of computers.

The combination of unique research capabilities in the DOE laboratory system and a focus on long-term development has the potential to realize a transformed CESM enterprise that will serve as a truly national resource.

Performance Engineering of the Community Climate System Model (PECCSM)

PRINCIPAL INVESTIGATOR: Patrick H. Worley (Co-PI with Arthur A. Mirin, LLNL)

SPONSOR: US DOE, Office of Science, Office of Advanced Scientific Computing Research

PARTICIPATING STAFF: Collin B. McCurdy

PARTNERS: Lawrence Livermore National Laboratory

PROJECT START DATE: October 1, 2009

PROJECT END DATE: September 30, 2011

PROJECT DESCRIPTION

PECCSM continues the research activities of the project "Performance Engineering for the Next Generation Community Climate System Model" (7/2006-6/2009). PECCSM has two primary goals: 1) to enable the Community Climate System Model (CCSM) to make effective use of current high performance computers systems at scale, and 2) to prepare future generations of the CCSM to make effective use of next generation high performance computing systems. The CCSM has evolved recently to become a first-generation Earth system model that treats the coupling between the physical, chemical, and biogeochemical processes in the climate system, and has been renamed the Community Earth System Model (CESM). The CESM will be used to explore new science and run simulations at higher resolution than previous state-of-the-art models. Both the improved physical processes and increased resolution come at the cost of significant increase in computational complexity. Thus, it is critical that the model run efficiently on the existing high performance computing platforms and that it be easily adapted to run efficiently on next-generation exascale-class systems characterized by massive parallelism and heterogeneous compute elements.

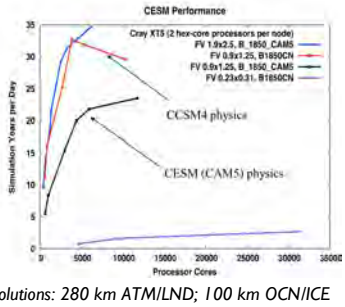
The PECCSM project is analyzing the performance of the CESM on DOE Leadership Class Computing systems, proposing and guiding performance improvements. The CESM is being evaluated not only in its present form and on current systems, but also in prototype configurations utilizing very high resolutions and comprehensive earth system processes and targeting prototype next-generation computer systems. Optimizations are being identified that will allow the CESM to more effectively use these architectures at the processor level, at the node level, and at the whole system level. Project members are collaborating with computing center, machine vendor staff and the computer science research community to identify system behavior that degrades the performance of the CESM in order to improve the relevant system software and to contribute to the specification of future-generation high-performance computing architectures.

SIGNIFICANCE

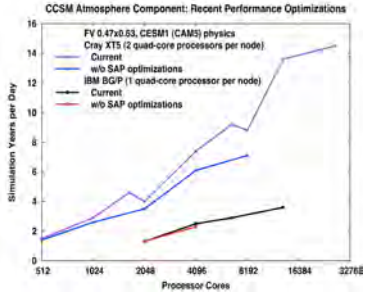
CESM is one of the world's leading climate models. Its predecessor the CCSM was an important contributor to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change and is expected to play just as significant of a role in the upcoming Fifth Assessment Report. Improved performance of CESM will accelerate climate science by increasing the ability to quantify impacts and assess strategies by increasing throughput for current simulations and making new, more computationally expensive, experiments feasible.

INTERESTING FINDINGS

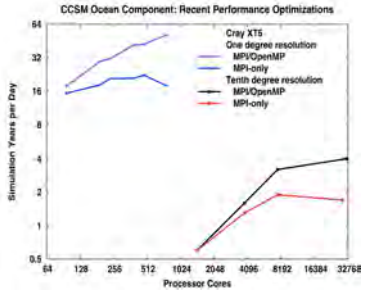
The April 2010 release of CCSM and June 2010 release of CESM included significant improvements to performance and scalability contributed by this project and its predecessor. Contributions more than doubled performance of the models.



Resolutions: 280 km ATM/LND; 100 km OCN/ICE
140 km ATM/LND; 100 km OCN/ICE
35 km ATM/LND; 10 km OCN/ICE



70 km ATM/LND grid, CAM5 physics



100 km and 10 km OCN grid
(30,000 core results preliminary, July 2010)

Development of Frameworks for Robust Regional Climate Modeling

PRINCIPAL INVESTIGATOR: Moetasim Ashfaq

PROJECT START DATE: 2010

PROJECT END DATE: 2013

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Pacific Northwest National Laboratory (Lead)

PROJECT DESCRIPTION

We propose a hierarchical approach to test the veracity of the global high resolution, global variable resolution, and nested regional climate model for regional climate modeling. We hypothesize that systematic evaluation of different modeling approaches, in the context of interactions across spatial/temporal scales and between the atmosphere, land, and ocean systems, will lead to better understanding of the relative merits of different dynamical approaches and improve the frameworks for robust simulations of regional climate. Our evaluation hierarchy has four stages: 1) idealized, no physics test cases, 2) idealized, full physics test cases, 3) real world, atmosphere-only and ocean-only simulations, and 4) real world, coupled atmosphere-ocean simulations for both current and future climate. We will use the regional hydrologic cycle as our scientific thrust for developing and evaluating frameworks for robust regional climate modeling. Since the regional hydrologic cycle can manifest differently in different climate regimes, we will use North and South America as our geographic focus to highlight several distinctive features.

SIGNIFICANCE

Predicting the regional hydrologic cycle at time scales from seasons to centuries is one of the most practical yet challenging goals of climate modeling. Water supports the ecosystems as well as a wide range of human activities such as energy, agriculture, and transportation. Climate models have projected increasingly uneven distributions of water both spatially and temporally and more frequent extremes, motivating the need for more research to improve regional predictions of the hydrologic cycle to address climate change impacts, adaptation, and mitigation.
A myriad of processes are responsible for the formation of clouds and precipitation, which provide the dominant forcing for the surface water budgets. To date, limitations in model simulations of clouds constitute a major uncertainty in climate predictions for the future. Thus, besides meeting societal needs, improving model skill in simulating the regional hydrologic cycle is an important benchmark for global and regional climate models. Because hydrologic cycle processes are inherently multi-scale, it has been postulated that increasing model resolution to more explicitly represent finer scale processes is a key to improving simulations of the hydrologic cycle.

Scalable, Efficient, and Accurate Community Ice Sheet Model (SEACISM)

PRINCIPAL INVESTIGATOR: Katherine J. Evans

PARTICIPATING STAFF: Patrick H. Worley, Jeffrey A. Nichols, Matthew R. Norman

PROJECT START DATE: November 1, 2009

PROJECT END DATE: October 1, 2012

SPONSOR: US DOE, Office of Science, Advanced Scientific Computing Research (ASCR)

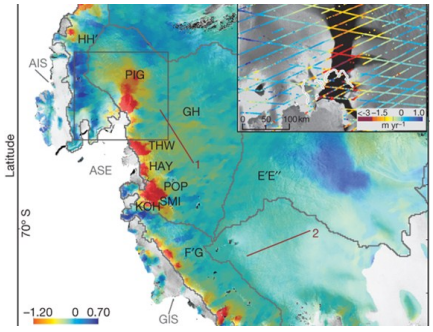
PARTNERS: Los Alamos National Laboratory, New York University, Sandia National Laboratory, Florida State University

PROJECT WEBSITE: http://www.csm.ornl.gov/SEACISM/

Glacier National Park, Alaska, July 2008

PROJECT DESCRIPTION

SEACISM is one of six projects launched from ASCR's Scientific Discovery through Advanced Computing (SciDAC)-funded ISICLES (Ice Sheet Initiative for Climate ExtremeS) initiative, which aims to yield high-fidelity, high-resolution ice sheet simulations. The goal of the SEACISM project is to develop a scalable, efficient, and accurate Community Ice Sheet Model (Glimmer-CISM). A state-of-the-art algorithms and tools framework has been developed within which climate model developers can create a predictive ice sheet modeling capability. A fully integrated parallel hierarchical blocking structure will allow maximum use of the latest high-performance computing architectures. An implicit solution algorithm with scalable preconditioning has been implemented using the Trilinos package of solvers to maintain efficiency with resolution and physical enhancements of ice representation. ASCR's Leadership Computing Challenge program granted SEACISM researchers 5 million processor hours on Jaguar at the Oak Ridge Leadership Computing Facility and another 1 million hours on Intrepid, Argonne National Laboratory's leadership computing facility system.



Rate of elevation change of Coastal West Antarctica

CISM has short-term requirements to provide accurate, quantitative estimates of ice sheet behavior, so the project will provide initial throughput gains for practical use. The model will be developed in extensible form such that ongoing code improvements will transfer to the climate model development effort with minimal structural modification. CISM has already been coupled as a component of the Community Earth System Model (CESM); the computationally-modern Glimmer-CISM could provide a template for the next generation of other climate model components in the CESM. At the completion of the project, the model will allow users to utilize demonstrably scalable solution algorithms and high-performance computing tools and allow for the incorporation of future improvements.

SIGNIFICANCE

The need for research to provide simulation data about ice sheet dynamics arose from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) which did not provide a prediction of ice sheet fate due to a lack of data. All six of the ISICLES projects, including SEACISM, respond to the national and international need to provide better ice sheet dynamics simulations in Earth system models to more accurately predict the behavior of ice sheets under a changing climate. SEACISM researchers hope their ice sheet model improvements will allow climate scientists to provide simulation data about ice sheet dynamics that will inform the Fifth Assessment Report of the IPCC, expected in 2013.

INTERESTING FINDINGS

SEACISM researchers recently incorporated a new solution method into Glimmer-CISM that provides nonlinearly converged solutions for improved accuracy and much faster (order of magnitude) solution speeds for a given problem. Current work involves the extension of an early version of a decomposed version of the code for highly parallel simulations and development of a preconditioner to the new solution method to allow even faster and more robust simulations.

Ultra High-Resolution Global Climate Simulation Project

PRINCIPAL INVESTIGATOR: James J. Hack

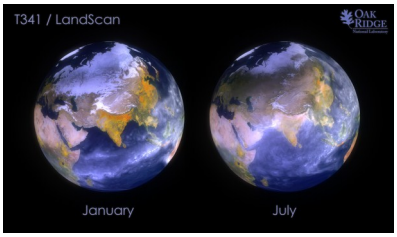
PARTICIPATING STAFF: Richard K. Archibald, Moetism Ashfaq, Gautam Bisht, Katherine J. Evans, Raymond E. Flannery, Daniel S. McKenna, Jeffrey A. Nichols, Patrick H. Worley

PROJECT START DATE: January 2010

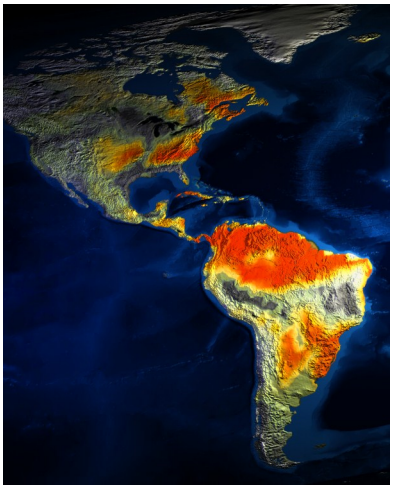
PROJECT END DATE: September 2014

SPONSOR: US DOE, Office of Science, Biological and Environmental Research

PARTNERS: Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory



This visualization uses the new CAM4, for the preindustrial 1850 period, spectral dynamic core at T341 truncation, which is about a 37km horizontal grid resolution. This configuration is currently under development by climate scientists at ORNL and NCAR in order to quantify the benefits and costs of climate simulation using higher resolution models.



The instantaneous Net Ecosystem Exchange (NEE) a measure of the atmospheric-terrestrial exchange of carbon as simulated with a version of the CCSM3 model that includes a terrestrial carbon modeling capability.

PROJECT DESCRIPTION

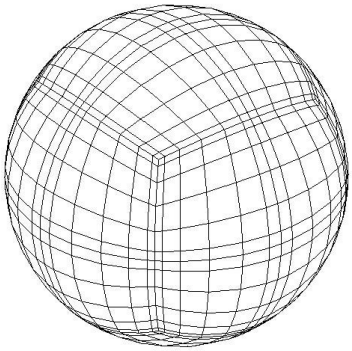
The problem of predicting climate change and its consequences is motivated by the increasingly urgent need to adapt to near term trends in climate change and the potential changes in the frequency and intensity of extreme events. This project is developing the scientific framework to determine the benefit of employing very-high-resolution global models to investigate regional-scale phenomena. The team will test the hypothesis that higher resolution models are necessary to accomplish the related objectives of 1) the explicit simulation of non-linear phenomena and interactions on the small scale that have feedbacks on large scale climate features; and 2) the accurate and explicit simulation of local to regional scale phenomena, including low-probability, high-impact hydrological events. The focus will be a rigorous evaluation of our hypothesis with high-resolution simulations of observed climate and variability will be the focus. Using a series of stand-alone component and ensemble coupled present-day climate simulations, the project partners will perform comparisons of high- and low-resolution model configurations to determine the potential advantages of high resolution simulations. They will investigate the role of air-sea interaction, the quality of the basic state, and resolution sensitivity on a hierarchy of modes of variability, including the distribution and evolution of extreme events in control, historical, and time-slice experiments of future climate change. An integral component of this project will be the development of new objective diagnostics and metrics to gauge the potential benefit of employing high resolution to improve the representation of regional scale phenomena, especially those related to the hydrological cycle.

The pathway to the project's goals requires an improved understanding of critical sensitivities in model formulation that have been identified from preliminary very-high resolution coupled simulations. Our experimental protocol will enable the project team to investigate these sensitivities, which include the interaction of physics with the choice of dynamical core of the atmospheric model and the initialization of the ocean model, both of which contribute to the development of model biases relative to observations. Implicit on this pathway toward developing a more realistic very-high resolution coupled model for regional projections of climate change will be the exploration of the benefit of very-high resolution contributed by the atmospheric and ocean models, respectively.

SIGNIFICANCE

Developing a coupled ocean-atmosphere model provides a great challenge to mod-

elers. This challenge is amplified when development is performed at very-high resolution, as scales of variability are resolved that heretofore have not been simulated in coupled mode, and due to the extreme computing that is required to produce such simulations. The climates of these very-high resolution runs each appear relatively stable. Thus, this project will investigate the sources of bias that complicate the simulation of the coupled system, including ocean initialization, parameterized physics and its interaction with the dynamical core. Additionally, the relative influence of high resolution from the atmospheric and ocean models will be explored through combinations of uncoupled and coupled runs in which the resolution of either one or both of the model components is decreased. The enhanced understanding and improved performance that we gain from the initial phase of experimentation will enable the project team to use the very-high resolution coupled model with increased confidence for the investigation of natural variability and anthropogenic forced perturbations in experiments run as part of the World Climate Research Programme's Working Group on Coupled Models Fifth Coupled Model Intercomparison Project (CMIP5) protocol.



Depicts cubed sphere geometry, where the transformation between the inscribed cube and the sphere is determined by the gnomonic (center) projection from the sphere to each face of the cube. This geometry is used for spectral element methods that have been demonstrated to be scalable dynamic cores (HOMME).

INTERESTING FINDINGS

This project is organized around eight experiments which will drive the results, analysis and reporting of findings over the next four years using four significant CESM components: CAM4 (the Community Atmosphere Model with spectral dynamical core), the Community Land Model (CLM), the parallel Ocean Program (POP) and the Community ICE Model (CICM).

1. T85 CAM/CLM with 1° POP/CICE (5 member ensemble) 30 years each
2. T85 CAM/CLM with 0.1° POP/CICE (single experiment) 30 years
3. T341 CAM/CLM with 1° POP/CICE (single experiment) 30 years
4. T341 CAM/CLM with 0.1° POP/CICE (5 member ensemble) 30 years each
5. Climate change runs: continue each of the above runs in (4) to 2035 using RCP 4.5 (30 years each)
6. Pre industrial control (1850 conditions) 186 years.
7. Single historical run 1850-2008. 158 years
8. A 1%/yr increasing CO2 starting in 1850 to doubling. 70 years

Visual Data Exploration and Analysis of Ultra-Large Climate Data

PRINCIPAL INVESTIGATOR: Sean Ahern (Local PI)

PARTICIPATING STAFF: George Ostrouchov, David Pugmire

PROJECT START DATE: May 1, 2010

PROJECT END DATE: April 30, 2013

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Lawrence Livermore National Laboratory (LLNL), Lawrence Berkeley National Laboratory (LBNL), University of California at Berkeley (UC-Berkeley), and Los Alamos National Laboratory (LANL)

PROJECT DESCRIPTION

The ORNL project team, consisting of climate, computational, and computer scientists, aims to develop, deploy, and apply parallel-capable visual data exploration and analysis software infrastructure to meet specific needs central to the DOE-BER climate science mission. The team's approach focuses on using a set of science drivers, which reflect challenges in understanding regional-scale climate-change phenomena, as the basis for a coordinated effort that includes visualization of ultra-large data, statistical analysis, and feature detection/tracking techniques. The aim is to deliver new capabilities needed by the climate science community to tackle problems of the scale required by Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (AR5) objectives. The collective team will focus their efforts on the comprehensive collection of near-term simulations that ORNL team members will conduct using the DOE/National Science Foundation (NSF) Community Climate System Model (CCSM) in support of DOE's contributions to the AR5. Software will be delivered to the climate community via CDAT, a well-established software framework for climate data access and analysis. This approach ensures that the proposed technology advances meet specific DOE mission-critical climate science needs, and that the resulting technology will reach a large audience in the climate science community via deployment in a well established and widely used software framework.

SIGNIFICANCE

This project focuses on advancing an integrated visualization and analysis framework for scientific discovery from ultra-high-resolution simulations of near-term climate change. Initial milestones of the project will center on the comprehensive collection of near-term simulations using the DOE/NSF CCSM in support of DOE's contributions to AR5. The project is designed to align directly with the BER long-term measure in climate-change research, namely to:

> "Deliver improved scientific data and models about the potential response of the Earth's climate and terrestrial biosphere to increased greenhouse gas levels for policy makers to determine safe levels of greenhouse gases in the atmosphere."

Our objective is to transform our ability to visualize and analyze the ultra-high-resolution simulations that will increasingly underpin national and international assessments of climate change.

Data Integration, Dissemination and Integration

ORNL is the home of two major observational climate data archives and a participant in a federated model climate data distribution system. The goal of the Data research theme is to "fuse" diverse environmental data—both observational and model based—and incorporate information from other sources to create knowledge about the evolving changing climate system and the broad range of spatial and temporal scales that are the foci of the CCSI research agenda. Topics within this theme range from the real-time acquisition and archival of experimental data from field experiments, to research development of advanced analytical tools for multi-petabyte remotely sensed data. Focuses within the Data Integration, Dissemination, and Informatics theme include:

- Data Engines for Model-Data Fusion
- Climate Data Systems Federation
- Advanced Climate Analytics and Climate Visualization Techniques
- Data Mining and Knowledge Discovery

Atmospheric Radiation Measurement (ARM) Data Archive

PRINCIPAL INVESTIGATOR: Raymond A. McCord

PARTICIPATING STAFF: John D. Bell, Sigurd W. Christensen, Bill Jackson, Dale P. Kaiser, W. Christopher Lenhardt, J.F. Manneschmidt, Giriprakash Palanisamy, Stephanie H. Shamblin, David E. Sill

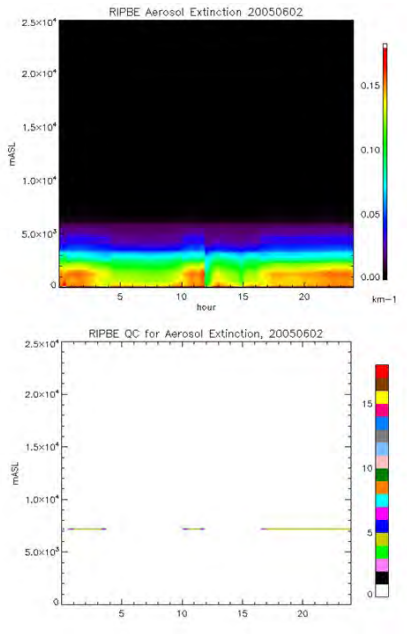
PROJECT START DATE: 1992

PROJECT END DATE: Ongoing

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories

PROJECT WEBSITE: http://www.archive.arm.gov/

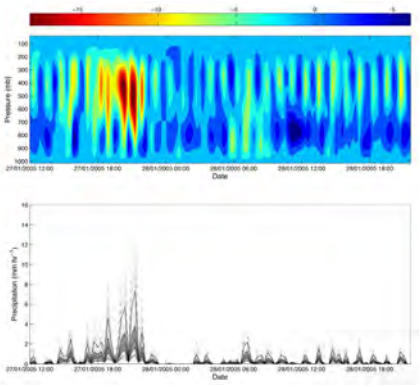


RIPBE for Southern Great Plains. The upper panel shows the output aerosol extinction field in Radiatively Important Parameters Best Estimate (RIPBE), and the bottom panel shows the quality control (qc) flags on aerosol extinction. Descriptions of the quality control flags are given in the netCDF file header. In this case, the gold and pink qc flags on the aerosol extinction indicate periods at the top of the aerosol profile where data were missing in the input file. These data points are marked as indeterminate, and RIPBE either interpolates over the missing data (gold) or uses the closest good value (pink).

PROJECT DESCRIPTION

The ARM Program was created to develop several highly instrumented ground stations to study cloud formation processes and their influence on radiative transfer. This scientific infrastructure includes two mobile facilities, an aerial facility, and data archive available for use by scientists worldwide through the ARM Climate Research Facility (ACRF). The primary objective of the ARM Project is improved scientific understanding of the fundamental physics related to interactions between clouds and radiative feedback processes in the atmosphere. The ARM Archive provides storage and access to all of the data generated or assembled by the ARM Program and the ACRF. The Archive provides access to data files by way of internet access to any researcher that submits data requests. The Archive supports hardware for data-intensive processing associated with reprocessing and processing of very large data sources, and also provides assistance with reprocessing and large data processing tasks (retrieving input, installing and supervising processing tools, storing results).

The Archive includes several integrated components that provide basic storage and retrieval services. The functional components include: a data reception and cataloging system, a database for metadata about the millions of stored files, a user interface and web server for data retrieval specification, and a mass storage system (automated tape libraries) for file storage. The storage processing component of the Archive records information about the data files (name, size, date received, etc.) and supervises the distribution of the data files to the permanent storage (mass storage system and backup copy). The database not only tracks the inventory of the Archive, it also supports searches for requested data based on sites, facilities, date range, instruments, and measurements. The database monitors incorrectly named data files and files with insufficient documentation, and also controls the retrieval of requested files and generates reports on data usage and user attributes. The web hosted user interfaces include query, catalog, and graphics based logic. The mass storage system includes a hierarchy of disk and tape storage media. It is capable of storing millions of data files and 100's of terabytesof data. It can also store or retrieve 100's of gigabytes of data per day. The Archive also includes an online storage structure and navigation interface for non-continuous and specialized measurements generated by the ARM Intensive Operational Periods.



Long-Term, Large-Scale Ensemble Forcing Data Set for Darwin. The lower panel shows 100 precipitation time-series derived given potential errors in radar-retrieved rainfall estimate. These time-series are an important input to the variational analysis used to create the ensemble large-scale data set. The different precipitation time-series modify the large scale data, particularly the derived vertical velocity. The upper panel shows the profile of vertical velocity derived using a best-estimate precipitation time-series. Strong rainfall is clearly associated with strong vertical motion in the mid- and upper-levels.

SIGNIFICANCE

The ARM program conducts scientific field experiments studying atmospheric radiation balance, cloud feedback processes, and other atmospheric and environmental issues. Information gleaned from these field experiments is meant to improve scientific understanding of atmospheric radiative energy transfer, cloud formation, and the parameterization of these functions in general circulation models (GCM) for global climate change research. Measurements collected by the ACRF include numerous parameters about radiation, meteorology, water vapor, aerosols, and clouds. These measurements generate enormous amounts of data, which are made available to the scientific community through the World Wide Web. The Archive is the chief repository for these data and provides a gateway for access to them. The ARM Data Archive is intended to facilitate climate change research by providing climate related data about the Earth's atmosphere in standardized formats free of charge. New efforts are now included to add high value data sets from the ARM Archive and Carbon Dioxide Information and Analysis Center (CDIAC) data center into the Earth System Grid "data environment." This will further facilitate climate modeling researchers working with climate observations during the evaluation of model results.

Carbon Dioxide Information Analysis Center (CDIAC)

PRINCIPAL INVESTIGATOR: Thomas A Boden (CDIAC Director)

PARTICIPATING STAFF: Robert J. Andres, T.J. Blasing, Sigurd W. Christensen, Lianhong Gu, Les A. Hook, Dale P. Kaiser, Alexander Kozyr, Misha B. Krassovski, Gregg Marland, Lisa M. Olsen, Bai Yang

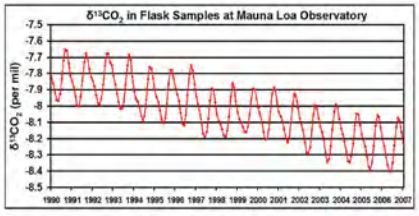
PROJECT START DATE: January 1, 1982

PROJECT END DATE: Ongoing

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: National Aeronautic and Space Administration's (NASA), National Oceanic and Atmospheric Administration, US Department of Agriculture, National Science Foundation, US Geological Survey, US Global Change Research Program

PROJECT WEBSITE: http://cdiac.ornl.gov/



As part of a larger effort to increase user access to carbon isotope data, CDIAC has a link to the National Oceanic and Atmospheric Administration (NOAA), Earth System Research Laboratory (ESRL) carbon-13 flask data files.

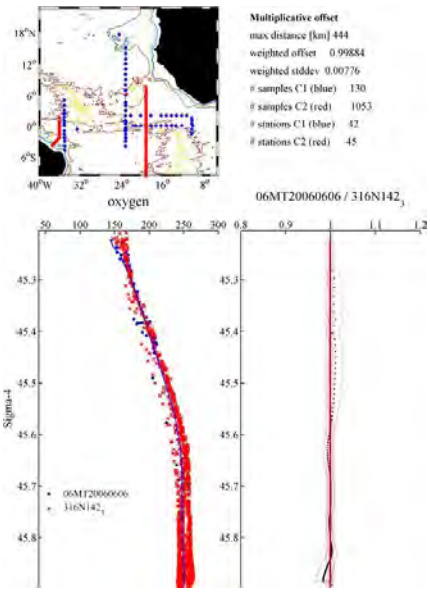
PROJECT DESCRIPTION

The Carbon Dioxide Information Analysis Center (CDIAC) is the primary climate-change data and information analysis center of the U.S. Department of Energy (DOE). CDIAC is located at ORNL and includes the World Data Center for Atmospheric Trace Gases.

CDIAC's data holdings include records of the atmospheric concentrations of carbon dioxide (CO_2) and other radiatively active gases; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of carbon dioxide from fossil-fuel consumption and land-use changes; long-term climate trends; the effects of elevated carbon dioxide on vegetation; and the vulnerability of coastal areas to rising sea level. CDIAC provides data management support for major projects, including the AmeriFlux Network, continuous observations of ecosystem level exchanges of CO_2, water, energy and momentum at different time scales for sites in the Americas; the Ocean CO_2 Data Program of CO_2 measurements taken aboard ocean research vessels; DOE-supported FACE (Free Air CO_2 Enrichment) experiments, which evaluate plant and ecosystem response to elevated CO_2 concentrations, and HIPPO (High-Performance Instrumented Airborne Platform for Environmental Research Pole-to-Pole Observations), which measures greenhouse gases and other relevant atmospheric species pole-to-pole.

SIGNIFICANCE

The Carbon Dioxide Information Analysis Center (CDIAC) serves as the primary climate-change data and information analysis center for DOE. CDIAC responds to ~ 350,000 data and information requests annually from users worldwide. The CDIAC provides data in many environmental subject areas: carbon cycle, climate, coastal sensitivity to sea level rise; energy and socioeconomic systems; land-use and ecosystems; oceanic trace gases; solar and atmospheric radiation; trace gas emissions; vegetation response to CO_2 and climate; fossil-fuel CO_2 emissions; atmospheric trace gas measurements; and terrestrial carbon management. CDIAC's diverse data collection includes the world's largest collection of ocean carbonate chemistry measurements and estimates of car-



Offset found between two cruises for oxygen. Crossover analysis is an objective comparison of deep water data from one cruise with data from other cruises in the same area.

Tanhua, T. 2010. Matlab Toolbox to Perform Secondary Quality Control (2nd QC) on Hydrographic Data. ORNL/CDIAC-158. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee. doi:10.3334/CDIAC/otg.CDIAC_158

bon releases from fossil-fuel consumption at global, regional, and national scales. The CDIAC facilitates the exchange of data and access to data, helps improve and maintain the quality of valuable data sets, and provides value-added services to climate researchers. CDIAC's gridded fossil-fuel CO_2 emission data are being used as baseline data for the IPCC AR5 model runs.

INTERESTING FINDINGS

CDIAC has served as the primary climate-change data and information analysis center of DOE since 1982. For nearly 30 years, CDIAC has provided climate scientists with data and information from a variety of climate-related areas that are critical to valid climate research. CDIAC is continually providing new climate change products. Most recently, CDIAC has provided a link to the National Oceanic and Atmospheric Administration's Earth System Research Laboratory carbon-13 flask data files in an effect to increase user access to carbon isotope data. In August of 2010, The Matlab Toolbox to Perform Secondary Quality Control on Hydrographic Data became available at CDIAC. This package allows crossover analysis to be performed.

Also in August of 2010, two new data sets were made available on the CDIAC Web servers. The first is an annual update to global, regional, and national fossil-fuel CO_2 emissions, which contains estimates of emissions from 1751 to 2007. The second takes those emissions and maps them on a 1^{o} degree latitude by one degree longitude basis for the entire globe. These data products were contributed by Thomas Boden, Gregg Marland, and Robert Andres. Recent CDIAC research results, publications, data products, and tools are highlighted monthly at **http://cdiac.ornl.gov/whatsnew.html**.

DataONE

PRINCIPAL INVESTIGATOR: Robert B. Cook (Co-PI)

PARTICIPATING STAFF: Giriprakash Palanisamy, James Green, Line Pouchard, and John Cobb

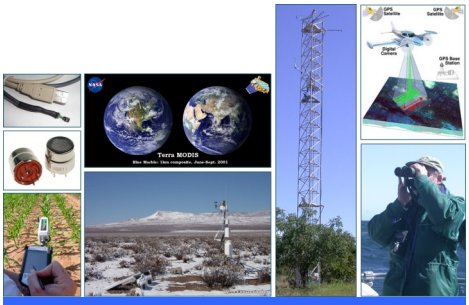
PROJECT START DATE: August 2009

PROJECT END DATE: Ongoing

SPONSOR: US National Science Foundation through a cooperative agreement with the University of New Mexico

PARTNERS: Cornell University; National Evolutionary Synthesis Center (Duke University); University of California – California Digital Library; University of California – Santa Barbra; University of Illinois – Chicago; University of Kansas; University of New Mexico; University of Tennessee – Knoxville; US Geological Survey (USGS); Utah State University

PROJECT WEBSITE: https://www.dataone.org/



Sensors, sensor networks, and remote sensing gather observations

Photo courtesy of www.carboafrica.net

PROJECT DESCRIPTION

DataONE is a cyber repository that provides universal access to data about life on earth and the environment that sustains it. DataONE supports environmental science by: (1) engaging the relevant science, data, and policy communities; (2) providing easy, secure, and persistent storage of data; and (3) disseminating integrated and user-friendly tools for data discovery, analysis, visualization, and decision-making.

The foundation for success with DataONE is the established partnerships among participating organizations that have decades-long expertise in a wide range of fields that include: existing archive initiatives, libraries, environmental observing systems and research networks, data and information management, science synthesis centers, and professional societies. DataONE engages its community of partners through working groups focused on identifying, describing, and implementing the DataONE cyber-infrastructure, governance, and sustainability models. These working groups, which consist of a diverse group of graduate students, educators, government and industry representatives, and leading computer, information, and library scientists will: (1) perform cutting edge computer science, informatics, and social science research related to all stages of the data life cycle; (2) develop DataONE interfaces and prototypes; (3) adopt/adapt interoperability standards; (4) create value-added technologies (e.g., semantic mediation, scientific workflow, and visualization) that facilitate data integration, analysis, and understanding; (5) address socio-cultural barriers to sustainable data preservation and data sharing; and (6) promote the adoption of best practices for managing the full data life cycle.

Environmental observations are stored in different observational models. For example, bird observation data are primarily held in an object-based data model (i.e., as a vector), while satellite imagery data is held in a field-based data model (i.e. a raster). Joining these data is an extremely challenging and time consuming task.

SIGNIFICANCE

The defining purpose of DataONE is to enable discovery and universal access to data about life on Earth from around the world through DataONE.org. DataONE achieves this vision by providing transformational tools that shape scientific understanding of Earth processes from local to global scales; offering researchers education and training in various domains to enhance scientific enquiry; combining expertise and resources across diverse communities to

collectively educate, advocate, and support trustworthy stewardship of scientific data; and presenting incentives and infrastructure for sharing data from federally funded researchers in academia. These objectives work in tandem to strengthen environmental research with an end goal of enabling discoveries that transform our understanding of ecological processes and conserve life on earth and the environment that sustains it.

NOTEABLE ACHIEVEMENTS

DataONE is currently developing infrastructure to provide support for the entire data life cycle, from obtaining observations, compiling documentation and metadata (information about the data product) that will help users understand the data, and other tools and services to allow users to explore the data holdings, access relevant data, and perform some analysis and visualization. The infrastructure is slated for release in January 2012.

DataONE has established a number of Working Groups in Community Engagement and in CyberInfrastructure to engage the international research community in identifying the best solutions for managing the data life cycle.
One of the first DataONE working groups is the Exploration, Visualization, and Analysis (EVA) group that examines data intensive science. Steve Kelling (Cornell Lab of Ornithology) and Bob Cook (ESD/ORNL) are the co-chairs of the EVA Working. The first exemplar dealt with the environmental factors that affect migratory bird distributions in the conterminous US (http://ebird.org/content/ebird/news/ebird-animated-occurrence-maps) . The methods used in exploring, visualizing and analyzing the bird observation and environmental data will inform the development of DataONE tools and services. The next exemplar for the EVA Working Group is associated with ILAMB's evaluation of carbon cycle models using a wide range of observations.

DAAC for Biogeochemical Dynamics

PI: W. Christopher Lenhardt

PARTICIPATING STAFF: Robert B. Cook, Benjamin McMurry, Tammy Beaty, Les A. Hook, Suresh K. Santhana Vannan, Ranjeet Devarakonda, Jerry Y. Pan, Carol Sanderson

Project Start Date: July 1994

Project End Date: September 30, 2014 (The ORNL DAAC is in its fourth 5-year interagency agreement.)

SPONSOR: National Aeronautics and Space Administration (NASA)

PARTNERS: The ORNL DAAC is one of the 12 science-focused data centers in the NASA Earth Observing System Data and Information System (EOSDIS).

Project Website: http://daac.ornl.gov

PROJECT DESCRIPTION

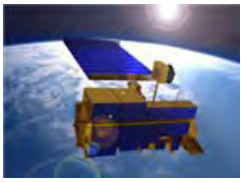
The mission of the ORNL DAAC is to assemble, distribute, and provide data services for a comprehensive archive of terrestrial biogeochemistry and ecological dynamics observations and models to facilitate research, education, and policy formulation in support of NASA's Earth sciences. This archive is used principally by researchers for studying global environmental change but is also used by a variety of other scientists. The archive includes both ground-based and remote-sensing measurements related to biogeochemical and ecosystem processes. Sources of data include NASA-funded field campaigns, selected relevant measurements from EOS satellites, and other biogeochemical dynamics data useful to the global change research community. The use of ground-based measurements is a key part of understanding the significance of EOS satellite data. Data from NASA and other sources archived at the ORNL DAAC are used to validate remote sensing data and to parameterize and validate models of local-, regional-, and global-scale processes for projecting changes in the Earth's ecosystems.

The ORNL DAAC is one of 12 science-focused data centers operating as part of the NASA EOSDIS (http://esdis.eosdis.nasa.gov/dataaccess/datacenters.html). The ORNL DAAC manages the data from NASA-funded field campaigns and serves as the science focus for terrestrial ecology for EOSDIS.

SIGNIFICANCE

Having reliable and easy access to data about the climate and the terrestrial ecosystem is critical for understanding climate change, improving models, and understanding impacts and vulnerabilities. The ORNL DAAC plays a key role in this effort, particularly as a bridge between the terrestrial ecology, remote sensing, and modeling communities.

INTERESTING FINDINGS



The ORNL DAAC hosts a number of different tools for accessing and delivering data, such as the MODIS (Moderate Resolution Imaging Sepctroradiometer) subsetting tool (http://daac.ornl.gov/MODIS/), which allows users to get MODIS land product data for small areas (up to 100 km x 100 km) and in easy-to use formats (ASCII and GeoTIFF). Some ORNL DAAC data is available using Open Geospatial Consortium (OGC) web services (http://webmap.ornl.gov/wcsdown/index.jsp) and using a browser-based Geospatial Information Systems (GIS) tool (http://webmap.ornl.gov/webgis/viewer.htm?instance=global). The ORNL DAAC is currently collaborating with the Alaska Satellite Facility to make Synthetic Aperture Radar data more accessible to the terrestrial ecology community.

Data Management Support for the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)

PRINCIPAL INVESTIGATOR: Robert B. Cook

PARTICIPATING STAFF: Giriprakash Palanisamy, Ranjeet Devarakonda, Ben McMurry, and James Green

PROJECT START DATE: 1999

PROJECT END DATE: December 2011

SPONSOR: NASA-Terrestrial Ecology Program

PARTNERS: Brazilian Ministry of Science and Technology (MCT); National (Brazilian) Institute for Research in Amazônia (INPA); and the LBA-Ecology (LBA-ECO) project at NASA

PROJECT WEBSITES:

http://lba.inpa.gov.br/lba/lba_ingles/?lg=eng
http://mercury.ornl.gov/lba/

PROJECT DESCRIPTION

The Amazon region of South America as viewed by MODIS on NASA's Terra satellite.

The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is an international research initiative led by Brazil. LBA is designed to create the new knowledge needed to understand the climatological, ecological, biogeochemical, and hydrological functioning of Amazonia, the impact of land use change on these functions, and the interactions between Amazonia and the Earth system.

LBA combines newly developed analytical tools and innovative, multidisciplinary, experimental designs in a powerful synthesis that will create new knowledge to address long-standing issues and controversies. LBA provides new understanding of environmental controls on flows of energy, water, carbon, nutrients, and trace gases between the atmosphere, hydrosphere, and biosphere of Amazonia to help provide the scientific basis of policies for sustainable use of Amazonian natural resources. The enhancement of research capacities and networks within and between the Amazonian countries associated with LBA will help advance education and applied research into sustainable development, and help in the process of formulating policies for the sustainable development of the region.

The Brazilian Ministry of Science and Technology (MCT) is responsible for the policy management of LBA. The National Institute for Amazonian Research (INPA) is responsible for the scientific coordination of the experiment and for its implementation. Created through an international cooperative agreement, LBA has important institutional relations, including ties with over 40 Brazilian institutions, 25 institutions from various Amazonian countries, as well as institutions from the US and 8 European nations.

Staff from ORNL's Environmental Sciences Division have provided data management support for over a decade to LBA. This support is focused on turning observations made in the Amazon into data products that are well-documented, quality assured, and ready to be curated at data archives in Brazil and at the ORNL DAAC.

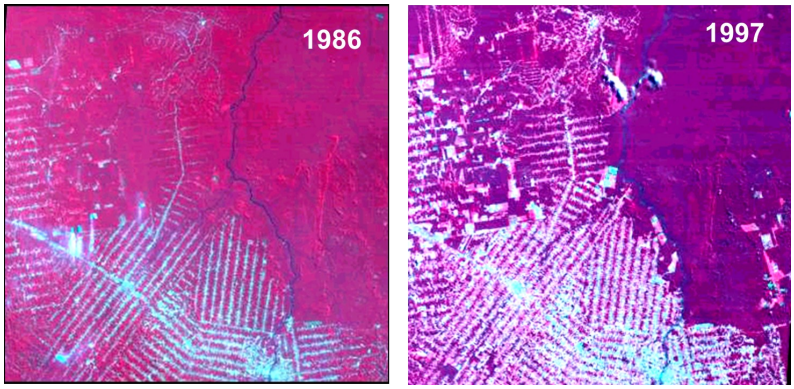
SIGNIFICANCE

LBA is centered around two key questions that is being addressed through multidisciplinary research, integrating studies in the physical, chemical, biological, and

human sciences: (1) How does Amazonia currently function as a regional entity, and (2) How will changes in land use and climate affect the biological, chemical and physical functions of Amazonia, including the sustainability of development in the region and the influence of Amazonia on global climate? In LBA, emphasis is given to observations and analysis which will enlarge the knowledge base for Amazonia in six general areas: Physical Climate, Carbon Storage and Exchange, Biogeochemistry, Atmospheric Chemistry, Hydrology, and Land Use and Land Cover. The program is designed to address major issues raised by the Climate Convention. It will help provide the basis for sustainable land use in Amazonia, using data and analysis to define the present state of the system and its response to observed perturbations, complemented by modeling to provide insight into possible changes in the future.

INTERESTING FINDINGS

A key legacy from the LBA Project is the data products archived at data centers in Brazil and at the ORNL DAAC. For the LBA-Ecology program, funded by NASA, the data are being archived at the ORNL Distributed Active Archive Center (DAAC). To date, the ORNL DAAC has archived 101 data sets and is scheduled to archive another 250 LBA-ECO products. LBA data are only being archived in Brazil and at the ORNL DAAC.



Central Rondonia, Brazil: Forest clearing 1986-1997 (Landsat imagery, forest=red) Courtesy TRFIC-MSU

NASA—Digital Object (ESDORA)

PRINCIPAL INVESTIGATOR: Jerry Y. Pan

PARTICIPATING STAFF: Giriprakash Palanisamy, Bruce E. Wilson, W. Christopher Lenhardt, Robert B. Cook, Biva Shrestha

PROJECT START DATE: January 10, 2010

PROJECT END DATE: December 31, 2011

SPONSOR: National Aeronautic and Space Administration (NASA)

PARTNERS: DuraSpace.org, University of Prince Edward Island, Johns Hopkins University

PROJECT WEBSITE: http://esdora.ornl.gov/

PROJECT DESCRIPTION

The goal for ESDORA is to deliver Earth sciences data, particularly the National Aeronautic and Space Administration's (NASA) Earth Observing System (EOS) data, using digital content repository technology, promoting best practice in digital provenance and enabling effective access to content and associated metadata.

Based on preliminary work, the ESDORA development team expects to couple the Fedora Repository and a Drupal-based graphic user interface (GUI) as key elements of a next-generation NASA Earth system science data center infrastructure, using datasets collected as part of the North American Carbon Program (NACP) Modeling and Synthesis Thematic Data Center (MAST-DC) as the primary science context. The team will use this implementation to enable better and more consistent access to critical metadata, including processing lineage information and administrative metadata, using the capabilities inherent in a digital repository (multiple streams for a given object and remote data streams). ESDORA seeks to demonstrate how data providers can more easily and effectively manage science data sets, associated metadata, processing lineage, and quality control/data provenance information. A consistent process, with associated user interfaces and application programming interfaces (APIs), can be used by the data provider to ingest, update, and modify a dataset for metadata changes or additional content dissemination revenues. Particularly in the context of the ORNL Distributed Active Archive Center data, this work will demonstrate potential technology migration paths for existing data operations.

SIGNIFICANCE

Digital content, including Earth science observations and model output, is an essential part of contemporary scientific research activities. Not only is the rate of archiving for such content increasing rapidly, but there is also an increase in derived and on-demand data product creation and consumption. As a result of these trends, scientific digital content has become even more heterogeneous in format and more distributed across the Internet. In turn, this makes the content more difficult for providers to manage and preserve and for users to locate, understand, and consume. Specifically, it is increasingly harder to deliver relevant metadata and data processing lineage information along with the actual content, particularly when there are multiple ways of delivering the content, including the increasing use of web services. Readme files, data quality information, production provenance, and other descriptive metadata are often separated in the storage level as well in the data search and retrieval interfaces available to a user. Critical archival metadata, such as auditing trails and integrity checks, are often even more difficult for users to access, if they exist at all. The development team behind ESDORA proposes to address these challenges by using and extending the capabilities of a contemporary digital object repository to work for science data and metadata delivery. Digital repository technology has been used for digital libraries with great success, and ESDORA seeks to apply this technology to the more complex needs of Earth science data management.

INTERESTING FINDINGS

Application of digital repository technology to data management is a new area of exploration, and this project is a pioneering experiment in this area. In our development effort, some of the advertised benefits as described in the above sections are largely attested and confirmed. For example, in metadata management, we have successfully configured

the system to use the FGDC-CSDGM (Federal Geographic Data Committee, Content Standard for Digital Geospatial Metadata) metadata record in addition to the required DC (Dublin Core) metadata for a data collection, from which chosen fields in both metadata records are searchable in the system. It should also be the case that an existing repository can change or add the metadata with a new standard such as ISO 19115. Additionally, dataset identification using Digital Object Identifiers (DOIs) is readily enabled by this system. The system is flexible and customizable, and we have just completed a modification to allow the file storage of content to be based on human-understandable hierarchy in order for the content to be easily accessible from other tools. However, there are also some challenges in using and promoting the technology. One such area, how to model content into digital objects (content modeling), is quite subjective, and it can vary from dataset to dataset. In addition, once a content model is used for real data, it is quite rigid, and radical changes of the model may prove to be costly for production system. The management and user access module (Islandora) is undergoing a lot of changes toward a more positive and user-friendly interface, but compared to mature, open source software, there are still some gaps in community adoption, documentation, and overall maturity.

Modeling and Synthesis Thematic Data Center (MAST-DC)

PRINCIPAL INVESTIGATOR: Robert B. Cook

PARTICIPATING STAFF: Daniel J. Hayes, Wilfred M. Post (co-I), Daniel M. Ricciuto, Peter E. Thornton (co-I), Yaxing Wei

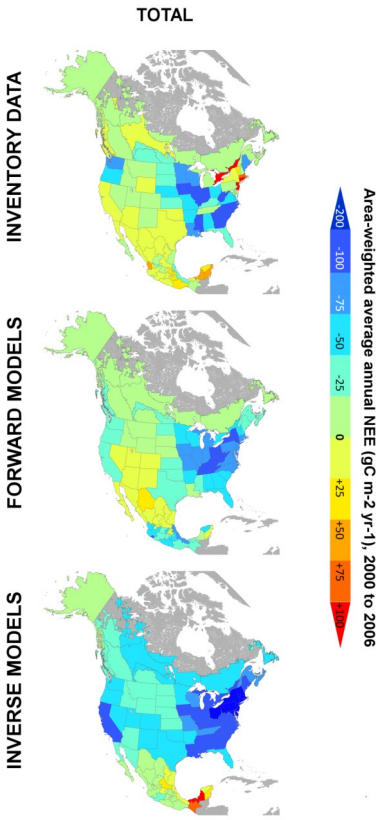
PROJECT START DATE: August, 27, 1998

PROJECT END DATE: September 30, 2012

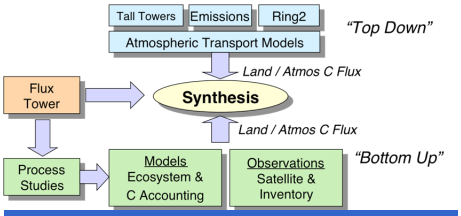
SPONSOR: National Aeronautic and Space Administration, Terrestrial Ecology Program

PARTNERS: Nearly 200 investigators from the international carbon cycle research community

PROJECT WEBSITE: http://nacp.ornl.gov



Mean area-weighted average annual NEE (gC m-2 yr-1), 2000 to 2006 for all land areas in each reporting zone, from inventory-based estimates against mean results from the sets of terrestrial biosphere models and atmospheric inverse models.



Compare fluxes and budgets obtained by complementary methods:

- *Bottom up inventories, Remote sensing and modeling, Atmospheric inversion and data assimilation*
- *Cross-scale: site, regional, continental*

PROJECT DESCRIPTION

The Modeling and Synthesis Thematic Data Center (MAST-DC) is a component of the data system of the North American Carbon Program (NACP; www.nacarbon.org) designed to support NACP by providing data products and data management services needed for modeling and synthesis activities. Based on specific requirements established by NACP, MAST-DC provides data products for modeling and synthesis in consistent and uniform grids, projections, and formats.

MAST-DC has compiled a wide range of observations, model input, and model output at a variety of scales (from flux towers to regions to all of North America) in close cooperation with the NACP community. These data products have been used in several NACP-wide synthesis activities to examine the spatial and temporal distribution of carbon sources and sinks as well as the processes influencing those sources and sinks.

SIGNIFICANCE

MAST-DC provides data products and services required by NACP in a central location, with common and co-registered spatial projections, in easily converted formats. MAST-DC frees modelers and those doing the synthesis and integration from having to perform many data management functions. Consequently, MAST-DC enables NACP participants to conduct their work more readily, facilitates the development of new model input needed by models, and assists in gaining new insights into the carbon cycle in North America.

INTERESTING FINDINGS

During the past three years, MAST-DC has coordinated the formation of several teams of NACP investigators to conduct an analysis of observations and model outputs for North America. An early part of this activity was identifying the characteristics of an integrated data product that could be used to conduct the analysis.

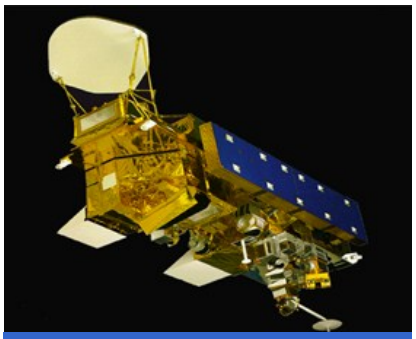
Analyses at individual flux towers indicated that the mean of the models outperforms the individual models, suggesting an ensemble model prediction approach may be the most effective. However, results from other synthesis groups revealed that there are specific cases where all models provide poor agreement, such as those results from agricultural systems, where nearly all models underestimate the intense carbon uptake rates observed in corn fields. Another example is in wetlands, where models generally fail to account for the

effects of water table depth.

Ground-based observations, like the respiration measurements made here, are compared with model output.

At a larger spatial scale, the NACP regional synthesis activity collected existing forward and inverse model simulations for North America. Observations were also compiled to validate the models, particularly forest and agricultural inventory data. Initial results from this intercomparison show that carbon cycle predictions are highly dependent on model structure, in particular the equations that govern photosynthesis.

The regional synthesis activity also confirmed the need for a standardized protocol, forcing data sets, and validation metrics for continental to global scale model simulations. This need will be fulfilled in part by MsTIMIP, the Multi-Scale Synthesis and Terrestrial Model Intercomparison NASA-funded project, led by Debbie Huntzinger (Northern Arizona University) and supported by MAST-DC. This project will also be closely coordinated with the International Land Model Benchmark (ILAMB) project, a model-data intercomparison and integration project co-led by CCSI Member Dr. Forrest Hoffman. ILAMB is designed to benchmark land surface models, improve the performance of land models, and improve the design of new observational campaigns. At the recent NACP All Scientist meeting, 34 investigators from 17 institutions in the US and Canada expressed interest in participating in the MsTIMIP and ILAMB activities.



Remote sensing observations from the MODIS sensor are essential for driving some models and for comparing with other models.

National Biological Information Infrastructure (NBII) Metadata Clearinghouse

PRINCIPAL INVESTIGATOR: Giriprakash Palanisamy

PARTICIPATING STAFF: Ranjeet Devarakonda

PROJECT START DATE: June 14, 2010

PROJECT END DATE: September 30, 2015

SPONSOR: US Geological Survey Biological Informatics Office

PARTNERS: NBII has a number of partners from agencies in the US federal, state, and local governments, as well as international, non-profit, private and multi-sector agencies and universities. A complete list can be found at: http://www.nbii.gov/portal/server.pt/community/nbii_partners/413.

PROJECT WEBSITE: http://mercury.ornl.gov/clearinghouse/about.jsp

PROJECT DESCRIPTION

The NBII Metadata Clearinghouse is a broad, collaborative program to provide increased access to data and information on the nation's biological resources. The Clearinghouse links diverse, high-quality biological databases, information products, and analytical tools maintained by NBII partners and other contributors in government agencies, academic institutions, non-government organizations, and private industry. NBII partners and collaborators also work on new standards, tools, and technologies that make it easier to find, integrate, and apply biological resources information. Resource managers, scientists, educators, and the general public use the NBII to answer a wide range of questions related to the management, use, or conservation of this nation's biological resources. The NBII Clearinghouse is an aggregator of metadata records, meaning that many different organizations provide records to be searched in one place. NBII Clearinghouse Partners maintain control of their metadata records, and provide access to them. NBII uses a weekly harvesting process, replacing records copied the week previous from each partner.
The NBII Metadata Clearinghouse can be searched by a term or phrase of interest from the Simple Search screen. The Advanced Search allows users to create a more complex or focused search by providing a variety of search parameters. After an initial search, the results page offers users the ability to filter results further, by narrowing the type of data, originator, and dates. In addition, data providers can be selected. This filtering process continues as users carry on their search. Clicking on “View Full Metadata” gives users a brief view of the record, but the user can choose to see a full metadata record describing the search topic.

SIGNIFICANCE

The NBII Clearinghouse contains metadata records describing datasets largely focused on wildlife biology, ecology, environmental science, temperature, geospatial data layers documenting land cover and stewardship (ownership and management), and more. The NBII provides visualizations of the data contained in the Clearinghouse to illustrate where the data are collected, and the types of data contained in the system. The NBII Clearinghouse is a powerful resource for scientists, allowing them to share and access information about important research in natural resources, much of which relates to climate change science. With over 93,000 records from over 85 data providers, the possibilities for collaborations and data exchange are endless—important factors to accurate climate change research.

NOTABLE ACHIEVEMENTS

NBII Metadata Clearinghouse has been actively harvesting new biological related metadata records, the system currently serves more than 93,000 metadata records from over 85 data providers with anticipation to cross 100,000 records by early 2011. The NBII Clearinghouse is using Mercury (http://mercury.ornl.gov) software toolset, which is an ORNL developed metadata management tool based on various opensource technologies.

National Biological Information Infrastructure (NBII) Metadata Clearinghouse

Standards supported in the NBII Clearinghouse: Metadata standards allow computers to exchange information easily, and allow users to access and compare information quickly and easily. The metadata records found in the NBII Clearinghouse follow the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata. Many of the records also utilize the Biological Data Profile, which are fields added to the standard that extend a record to include information about taxonomy, methodology, and analytical tools used in the creation of a dataset.

Scaling the Earth System Grid to Petascale Data

PRINCIPAL INVESTIGATOR: Galen M. Shipman

PARTICIPATING STAFF: Meili Chen, Ross G. Miller, Feiyi Wang

PROJECT START DATE: October 1, 2010

PROJECT END DATE: TBD

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Los Alamos National Laboratory (LANL), Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), National Center for Atmospheric Research (NCAR)

PROJECT DESCRIPTION

With prior Scientific Discovery through Advanced Computing (SciDAC) support, the research team has developed and deployed the Earth System Grid (ESG) to make climate simulation data easily accessible to the climate modeling community. ESG currently has 2500 registered users, and manages 160 terabytes (TB) of data in archives distributed around the nation. In this past year alone, more than 200 scientific journal articles have been published from analyses of data delivered by the ESG.

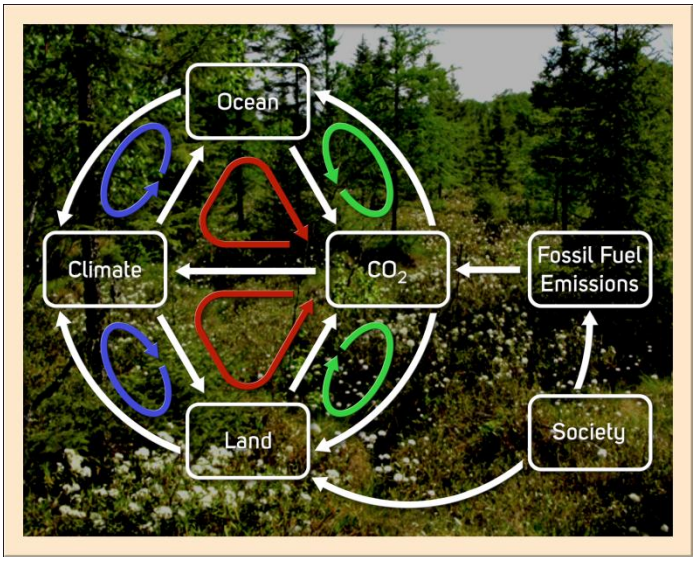
Despite these successes, ESG faces significant challenges in coming years as the size, complexity and number of climate datasets grows dramatically. The goals of this proposed five-year project are to (a) sustain the successful existing ESG system, (b) address projected scientific needs for data management and analysis, (c) extend ESG to support the major Intergovernmental Panel on Climate Change (IPCC) assessment in 2010, (d) support the Climate Science Computational End Station at the DOE Leadership Computing Facilty at ORNL, and (e) support climate model evaluation activities under the proposed SciDAC2 climate application. To do this, the team will broaden ESG to support multiple types of model and observational data, provide more powerful (client-side) ESG access and analysis services, enhance interoperability between common climate analysis tools and ESG, and enable end-to-end simulation and analysis workflow.

SIGNIFICANCE

DOE's investment in climate change research is broad, spanning model development, climate change simulation, model intercomparisons, observational programs, and supporting infrastructure for the Intergovernmental Panel on Climate Change (IPCC). Climate change research is increasingly data intensive, involving the analysis and intercomparison of simulation and observation data from many sources. Continued scientific progress depends upon powerful, effective enabling technologies that allow the core climate science community to coherently manage and publish a diverse collection of what in a few years will be petascale data, such that a broad, global community can access and analyze it.

This page left intentionally blank.

Terrestrial Ecosystem and Carbon Cycle Science



Prediction of future climate trajectories depends on prediction of the atmospheric concentration of CO_2 and other greenhouse gases and on prediction of the distribution, structure, and functioning of land ecosystems. The focus of the Terrestrial Ecosystem and Carbon Cycle Science theme is to improve projection of future CO_2 concentrations; strengthen understanding of ecosystem response to climate change; enhance integration of land-use and land-cover change in climate models; expand integration of observations, experimentation, and modeling across spatial scales from point to globe; and to focus on operational model development in context of the Community Climate System Model/Community Earth System Model. Focuses within the Terrestrial Ecosystem and Carbon Cycle Science theme include:

- Process Studies and Modeling
- Targeted Observational Programs
- Next-Generation Experimental Manipulations of Ecosystems
- Integration of Observation, Experimentation, and Modeling

Climate Change – Terrestrial Ecosystem Science SFA (Scientific Forcing Area)

CO-PRINCIPAL INVESTIGATORS: Paul J. Hanson and Peter E. Thornton

PARTICIPATING STAFF: Robert J. Andres, Lianhong Gu, Daniel J. Hayes, Les A. Hook, Colleen Iversen, Anthony W. King, Jiafu Mao, Melanie A. Mayes, Richard J. Norby, Wilfred M. Post, Daniel M. Ricciuto, Chris Schadt, Xiaoying Shi, Dali Wang, Jeffrey M. Warren, Dave Weston, Stan Wullschleger

PROJECT START DATE: October 1, 2009

PROJECT END DATE: Ongoing

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PROJECT WEBSITE: http://tes-sfa.ornl.gov

Aerial photograph of the landscape around the S1 Bog (October 2009)

Environmental Monitoring Station - S1 Bog

Experimental Chamber Prototype at ORNL

Understanding ecosystem carbon cycles and force responses in the context of climatic and atmospheric change is the focus of ORNL's research in the Terrestrial Ecosystem Science Focus Area. The combined efforts include large-scale manipulations, carbon cycle observations, process-level studies, and an integrating suite of modeling efforts.

Experimental work under the Terrestrial Ecosystem Science SFA focuses on the identification of critical response functions for terrestrial organisms, communities, and ecosystems. Both direct and indirect effects of these experimental perturbations are analyzed to develop and refine models needed for full Earth system analyses. ORNL's climate change manipulations are organized around a single climate change experiment focusing on the combined response of multiple levels of warming at ambient or elevated CO_2 (eCO_2) levels in a black spruce - sphagnum ecosystem in northern Minnesota. The experiment provides a platform for testing mechanisms controlling vulnerability of organisms and ecosystem processes to important climate change variables (e.g., thresholds for organism decline or mortality, limitations to regeneration, biogeochemical limitations to productivity, carbon evolution). The experiment will evaluate the response of existing biological communities to a range of warming levels from ambient to +9 ^{o}C. The +3 ^{o}C and +9 ^{o}C warming treatments will also be conducted at elevated CO_2 (in the range of 800 to 900 ppm). The target ecosystem located at the southern extent of the spatially expansive boreal peatland forests is considered to be especially vulnerable to climate change and to have important feedbacks on the atmosphere and climate. Our terrestrial ecosystem science plan also includes support for core, long-term tracking of the hydrologic, biogeochemical and biological response of the Walker Branch Watershed to inter-annual climatic variations.

Carbon cycle modeling and research involves the integration of biophysical, biochemical, physiological, and ecological processes into terrestrial ecosystem models that are optimally constrained in structure and function by historical and contemporary observations, and include mechanistic results of manipulative experiments to enable projections of future responses and feedbacks to climate forcing. ORNL's TES-SFA eliminates the artificial distinction between experimental and observational studies and model building, parameter estimation, evaluation, and projection. Advancing terrestrial carbon cycle science requires observations and measurements to be integrated with spatially resolved, mechanistic process-based models of terrestrial ecosystems that represent scientific understanding from experiments and are validated and constrained by observations and revealed by experimental manipulation. Only through such integration may we produce reliable estimates of sources and sinks of CO_2 and extrapolation from observations in space and time to novel environmental conditions of the future. Research will lead to an operational model framework in which observational and experimental studies and modeling activities at different spatial and temporal scales are integrated and used to estimate and mechanistically explain current carbon sources and sinks and forecast their future behavior and influence on atmospheric CO_2 concentration and climate.

Accurate representation of soil carbon cycling processes, particularly the response to short- and long-term environmental changes, is needed to improve predictions of regional- to global-scale climate models. Given recent process-level advances in our understanding of the chemistry of soil carbon storage and susceptibility, the accuracy of current models in predicting soil carbon response to environmental change is uncertain. Our goal is to generate mechanistically-based rate data to resolve recent questions regarding the nature of stabilized soil carbon, and to develop a process-level model describing soil carbon response to environmental change. The resulting model and description of soil carbon dynamics will be tested at ongoing SFA field experiments and against various long-term datasets at various spatial scales.

Activities supported include the following tasks and task leads in order of overall financial investment: SPRUCE Climate Change Experiment (Hanson et al.), Carbon Cycle Modeling (Thornton, Post, et al.), a process study of carbon allocation (PITS - Warren), soil carbon cycling process studies (Hanson, and Mayes), the MOFLUX contribution to AmeriFlux science (Gu), and carbon emissions research and synthesis (Andres).

Free-Air CO_2 Enrichment (FACE) Experiment

PRINCIPAL INVESTIGATOR: Richard J. Norby

PARTICIPATING STAFF: Joanne Childs, Colleen M. Iversen, Jeffrey M. Warren

PROJECT START DATE: October 1, 1996

PROJECT END DATE: September 30, 2011

SPONSOR: US DOE, Office of Science, Biological and Environmental Research

PARTNERS: Argonne National Lab, Chapman University, University of Illinois-Chicago, University of Tennessee.

PROJECT WEBSITE: http://face.ornl.gov/index.html

The ORNL FACE site was the cover photo for the November 9, 2010 edition of the Proceedings of the National Academy of Sciences.

CO_2 vent pipes above the canopy.

Aerial view of the FACE site.

Tower supporting CO_2 vent pipes.

PROJECT DESCRIPTION

The goal of the Oak Ridge Free-Air CO_2 Enrichment (FACE) project wa to understand how the eastern deciduous forest will be affected by CO_2 enrichment of the atmosphere and what the feedbacks are from the forest to the atmosphere. This goal was being approached by measuring the integrated response of an intact forest ecosystem, with a focus on stand-level mechanisms.

Stimulation of terrestrial plant production by rising CO_2 concentration is projected to reduce the airborne fraction of anthropogenic CO_2 emissions. Coupled climate-carbon cycle models are sensitive to this negative feedback on atmospheric CO_2, but model projections are uncertain because of the expectation that feedbacks through the nitrogen cycle will reduce this so-called CO_2 fertilization effect. We measured the effect of atmospheric CO_2 concentration on net primary productivity and related processes in a 12-year FACE experiment in a deciduous *Liquidambarital styraciflua* (sweetgum) forest stand on the Oak Ridge National Environmental Research Park. The FACE facility, comprising five 25 m plots, was constructed in 1997 in a sweetgum monoculture plantation that had been established in 1988. This closed-canopy, 18 m tall stand offered the opportunity for rigorous tests of hypotheses that address the essential features of a forest stand and how they could influence the responses to CO_2. These features included: (1) the closed canopy, which constrains growth responses; (2) full occupancy of the soil by the root system, which constrains the nutrient cycle; (3) the larger scale of the trees compared to saplings in open-top chambers, which changes the functional relationships of carbon cycling; and (4) the longer time scale that could be addressed, permitting studies of soil carbon changes.

SIGNIFICANCE

The response of natural ecosystems to an increasing concentration of CO_2 in the atmosphere is a key component of analyses of the current and potential impact of global change. Efforts to understand how eastern deciduous forests will be affected by CO_2 enrichment of the atmosphere have heretofore been addressed by studying components of the forest system (individual small trees, specific processes), but the FACE project took the critical leap to measuring the integrated response of an intact forest with a focus on stand-level mechanisms. Results from the FACE project provided a benchmark for coupled carbon cycle climate models used in 4th Assessment Report of the Intergovernmental Panel on Climate Change and data sets used by 20 modeling groups, and they are currently being used in a model intercomparison project at the National Center for Ecological Synthesis and Analysis.

Free-Air CO_2 Enrichment (FACE) User Facility Operation

Autumn color.

INTERESTING FINDINGS

Fine-root production was stimulated by elevated CO_2, especially deeper in the soil, leading to greater carbon input to soil and greater access to mineral nitrogen. Initial enhancement of net primary productivity was not sustained because of feedbacks through the nitrogen cycle. Stable isotope analysis indicated that nitrogen availability declined faster in plots exposed to elevated CO_2, consistent with model predictions. Carbon storage in the soil increased in CO_2-enriched plots, including in protected forms. Successional development of the understory community was accelerated in elevated CO_2.

Litter decomposition bags.

Monitoring equipment.

Improving the Representations of Human-Earth Interactions

PRINCIPAL INVESTIGATOR: Peter E. Thornton

PARTICIPATING STAFF: Marcia L. Branstetter, Jaifu Mao, Ben Mayer. Xiaoying Shi

PROJECT START DATE: April 1, 2009

PROJECT END DATE: March 31, 2014

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Pacific Northwest National Laboratory (PNNL), Lawrence Berkeley National Laboratory

PROJECT DESCRIPTION

The goal of this project is to strengthen the coupling between climate and Earth System Models (ESMs) and Integrated Assessment Models (IAMs). The research will address five central issues: 1) What is the influence of past, present and future land-use and land-use change on the evolution of the terrestrial carbon cycle, and what are its influences on the evolution of climate forcing in the future? 2) What is the potential for replacing fossil fuels with biofuels, and what are the implications of this substitution for climate forcings, and therefore the evolution of the climate system? 3) How does human decision-making on water use and water resources affect regional impacts of climate, given the changes in the hydrological cycle that will accompany a changing physical climate system? 4) What are the most important feedbacks of changes in the climate system on the evolution of carbon sources and sinks in the biosphere, and on human decision-making about energy futures? How do these feedbacks affect the evolution of the climate system over the coming decades to a century? 5) To what extent do human decisions about energy futures, and adaptation to changes in climate affect possible emissions pathways, and therefore the evolution of climate forcings and the physical climate system?

Four international IAM teams are each providing one Representative Concentration Pathway (RCP) (defined in terms of its radiative forcing in 2100). The PNNL MiniCAM team is the only US IAM team involved in this process. Its RCP (4.5 W/m^2) will be used by all climate modeling teams to drive both long-term climate ensembles and decadal climate forecast ensembles. Members of the ORNL and LBNL teams are instrumental in the development of the leading U.S. research ESM, the Community Climate System Model (CCSM), that will be used to simulate the scenarios and RCPs for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

SIGNIFICANCE

IAMs are the primary tool for describing the human-Earth system—the source of greenhouse gases, and short-lived species emissions and the system experiencing impacts of anthropogenic climate change. ESMs are the primary scientific tools for examining the climate and biogeophysical impacts of changes to the radiative properties of the Earth's atmosphere. This project integrates the economic and human dimension modeling of IAMs within fully coupled ESMs. By doing so, the team will improve climate predictions and enhance scientific understanding of climate impacts and adaptation opportunities. The research team will improve scientific understanding of the human-earth system dynamics, such as the interactions and feedback leading to the timing, scale and geographic distribution of emissions trajectories and other human influences, corresponding climate effects and the subsequent impacts of a changing climate on human and natural systems.

Investigation of the Magnitudes and Probabilities of Abrupt Climate Transitions (IMPACTS)

PRINCIPAL INVESTIGATOR: Wilfred M. Post (Site PI)

PARTICIPATING STAFF: Anthony W. King

PROJECT START DATE: July 1, 2008

PROJECT END DATE: June 30, 2013

SPONSOR: DOE, Office of Science, Biological and Environmental Research (BER)

PARTNERS: Purdue University, Argonne National Laboratory, Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory (Lead), Pacific Northwest National Laboratory, Los Alamos National Laboratory

PROJECT WEBSITE: http://esd.lbl.gov/research/projects/abrupt_climate_change/impacts/

PROJECT DESCRIPTION

IMPACTS is a project that brings together six national laboratories to attack the problem of abrupt climate change (ACC). The focus will be on the risk of ACC on decadal rather than centennial time scales. Some of the most significant mechanisms proposed for ACC will be investigated through a series of linked projects that examine:

- Dynamics of ice shelf — ocean interaction and evaluation of marine ice sheet instability,
- Boreal/Arctic-climate positive feedbacks and ACC,
- Rapid destabilization of methane hydrates in Arctic Ocean sediments, and
- Mega droughts in North America, including the role of biosphere-atmosphere feedbacks

Since this project is focused on the future risk of abrupt phenomena, the onset of these phenomena will be predicted using a detailed representation of the Earth system called the Community Climate System Model (CCSM). In order to quantify the risk of ACC, the team will add new capabilities and functionality to CCSM and its accompanying diagnostic packages. The team will enhance CCSM with representations of ice shelves, terrestrial methanogenesis, gaseous oceanic plumes, and vegetative controls on soil moisture and evapotranspiration. The team will also create new versions of CCSM that can generate equilibrated solutions for the coupled ocean-atmosphere system much more rapidly than is feasible using standard forward solution methods. The team will test that the new physics, chemistry, and biogeochemistry is consistent with the comparative stability of the recent climate record. The enhancements to CCSM and its diagnostics together with the resulting model simulations will be shared with the wider CCSM community.

ORNL is focused on the Boreal/Arctic-Climate Positive Feedback component of the overall project. Terrestrial ecosystems north of 45°N contain more than one-third of active terrestrial organic carbon, approximately 750 petagrams (Pg) of carbon , most of which resides in the soil. In addition, there are an estimated 455 Pg of carbon in large peatland basins and an additional 1000 Pg of carbon in yedoma and non-yedoma permafrost. This region has already experienced rapid changes in environmental conditions under current global warming. In particular, the spatial distribution of boreal and arctic vegetation types has started to shift with large consequences for snow cover and regional albedo. Although some degree of boreal/arctic feedback to warming is almost certain (indeed, has already been documented), there has been no comprehensive assessment of its likely magnitude—in part because the model capability has been lacking. The capability of CCSM will be extended by incorporating additional plant functional types for high latitude into the Climate Land Model-Nitrogen Cycle (dynamic vegetation) (CLM-CNDV) land surface model. Initial Community Atmosphere Model (CAM) (coupled to a slab ocean model) runs with static current vegetation, and CLM-CNDV's dynamic vegetation will be completed to investigate the potential impact of albedo feedbacks in the climate system. The impact of fires on the soil C cycle and shrub invasion will be quantified. Finally, simulations using CCSM fully coupled to the modified land-surface model will be repeated with CLM-CNDV's dynamic vegetation dynamics included.

Investigation of the Magnitudes and Probabilities of Abrupt Climate Transitions (IMPACTS)

SIGNIFICANCE

There is a pressing need to extend state-the-art land surface models and apply them to a global modeling evaluation of global abrupt climate change from the biophysical and greenhouse gas feedbacks generated by vegetation range shifts, biogeochemical dynamics, and climate forcing in the boreal/arctic regions. Even if these feedbacks are projected to not achieve sufficient strength and speed to cause abrupt climate change, they will still be playing an important role in future climate, and it will be valuable to quantify this amplification of anthropogenic radiative forcing.

Next-Generation Ecosystem Experiments-Arctic (NGEE)

PRINCIPAL INVESTIGATOR: Stan D. Wullschleger

PARTICIPATING STAFF: Dwayne Elias, David Graham, Baohua Gu, Daniel J. Hayes, Bob Hettich, Forrest M. Hoffman, Les Hook, Colleen M. Iversen, Alex Johs, Liyuan Liang, Melanie Mayes, Richard T. Mills, Richard J. Norby, Gerald Tuskan, Wilfred M. Post, Peter E. Thornton, Jeffrey M. Warren, David Weston

PROJECT START DATE: April 2010

PROJECT END DATE: Ongoing

SPONSOR: US DOE, Office of Science, Biological and Environmental Research

PARTNERS: Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Sandia National Laboratory, US Army Cold Regions Research and Engineering Laboratory, University of Alaska Fairbanks, University of New Hampshire

PROJECT WEBSITE: http://ngee.ornl.gov

Arctic tundra site on the Barrow Environmental Observatory, Barrow, Alaska

Arctic tundra site on the Barrow Environmental Observatory, Barrow, Alaska

PROJECT DESCRIPTION

The Arctic has emerged as an important focal point for the study of climate change. Characterized by its heterogeneous landscape and vast amounts of carbon stored in permafrost, this region is already experiencing rapid changes in climate, particularly temperature. It is a fragile landscape and highly sensitive to future environmental change. It is also a region that is critical to understanding how complex systems will respond to a changing climate *and* how processes underlying those changes can be represented in climate models. Improving climate prediction in high-latitude ecosystems will require understanding permafrost and snow dynamics and the many cascading impacts of a changing geophysical system on vegetation, subsurface processes, land-atmospheric interactions, and landscape processes.

In addressing this challenge, the Next-Generation Ecosystem Experiments (NGEE) project will address how experiments, observations, and process models can quantify the response of physical, ecological, and biogeochemical processes to atmospheric and climatic change across molecular to landscape scales. Our focus is on interactions that drive ecosystem-climate feedbacks through greenhouse gas fluxes and changes in surface energy balance. Fundamental knowledge will reduce uncertainty and improve representation of processes in Earth System Models. Specific goals are to:

- Understand and quantify the response and sensitivity of physical, ecological, and biogeochemical processes to atmospheric and climatic change across molecular to landscape scales, focusing on important interactions that drive regional and global climate feedbacks through greenhouse gas fluxes and changes in albedo.
- Use fundamental knowledge to improve representation of ecosystem dynamics, subsurface biogeochemistry, and land-atmosphere processes in regional and global models to reduce uncertainty and improve prediction of climate change in high-latitude ecosystems.

Our research approach is to conduct field and lab experiments and observations that together will advance our understanding of system-level behavior. Across these studies we will implement advanced monitoring approaches to quantify how continuous and threshold-dominated permafrost dynamics vary as a function of physical heterogeneity and temperature, and how these dynamics impact resource availability and microclimate that are important to the structure and function of tundra plant and microbial communities. Changes in vegetation dominance between shrubs, grasses, and forbs will create substantial ecosystem-climate feedbacks through changes in albedo, energy exchange, snow depth, timing and extent of permafrost thaw, microbial activity, and

US Army Corps of Engineers (USACE) Permafrost Tunnel Research Facility Fairbanks, Alaska

CO_2 and CH_4 uptake and release. The timing, rate, amount, and spatial distribution of greenhouse gas emissions from degrading permafrost will depend on complex interactions at the soil column to landscape scales between hydrology, soil physical and mechanical properties, above- and below-ground ecosystem processes, and soil carbon content and characteristics. It will be especially important that we identify key plant and microbial community interactions with the use of genomic, metabolomic and proteomic tools and measure CO_2 and CH_4 production in the field as well as in highly-instrumented microcosm and mesocosm studies.

SIGNIFICANCE

Prediction of global climate change at decadal to century time scales requires Earth system models that couple physical, biological, and ecological processes, capturing the most significant climate change drivers and representing critical feedback mechanisms. Unfortunately, while current models represent many of the processes that govern important land-atmosphere interactions, there is a continuing need for data to represent new processes in models, constrain model predictions, and test models against experimentally-derive datasets. Scientific investigation of the response of Arctic ecosystems to climate is critical to our overall understanding of the impacts of global environmental change. This is because this region is currently experiencing rapid changes in the climate system, the biophysical system of the Arctic is particularly vulnerable to these changes, and there is currently large uncertainty in the net effect of these biophysical changes and their feedbacks to climate. Current changes observed in the Arctic system may be a harbinger of near-future changes and their regional to global impacts at other latitudes.

Scientists observing Permafrost tunnel at USACE Permafrost Tunnel Research

INTERESTING FINDINGS

Understanding the vulnerability of Arctic ecosystems to climate change and their potential feedbacks at regional to global scales will require that we quantify mechanisms of response through process-level studies tied directly to GCM-scale process representations, and that we characterize spatial variation in mechanisms through observations. Such an effort will require that we use that fundamental knowledge to improve representation of ecosystem dynamics, biogeochemistry, hydrology, and land-atmosphere feedbacks in regional and global models to reduce uncertainty and improve prediction of climate and climate change in high latitude ecosystems. The NGEE project will describe how experiments, observations, and process models can address the sensitivity and vulnerability of Arctic ecosystems to atmospheric and climatic change. Field and laboratory studies will span genomics to geophysics, and will benefit from a bottom-up and top-down approach to understanding system complexity. This approach paces a priority on our ability to design experiments and observations that together aim to understand the interactions and feedbacks that occur between biological, geochemical, and landscape processes in the Arctic. Such an approach must consider how different components of complex systems are linked, and the interplay in space and time that determines system behavior.

Quantification and Reduction of Critical Uncertainties Associated with Carbon Cycle-Climate System

PRINCIPAL INVESTIGATOR: Peter E. Thornton (Local PI)

PARTICIPATING STAFF: Forrest M. Hoffman, Ben Mayer, Xiaoying Shi

PROJECT START DATE: July 7, 2010

PROJECT END DATE: June 30, 2013

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Lawrence Berkeley National Laboratory (LBNL), Los Alamos National Laboratory (LANL), University of California at Irvine (UC-Irvine)

PROJECT DESCRIPTION

Carbon cycle climate feedback uncertainties play a large role in defining the overall uncertainty envelope for predictions of future greenhouse gas concentration, terrestrial ecosystem structure and function, and associated climate changes. The processes thought to dominate the sign and magnitude of carbon-climate feedbacks vary across latitudinal zones, and integrated prediction of the global-scale feedbacks depends on detailed understanding of regional and zonal mechanisms connecting the terrestrial cycles of carbon and nutrients with the climate system.

The team's approach is: 1) to quantify critical uncertainties in global-scale climate predictions associated with carbon-climate feedbacks; 2) to improve our understanding and model representation of processes controlling these feedbacks through zonally-specific model-data evaluation exercises; and 3) to extend our data-based evaluation to quantification of carbon-climate feedback responses and uncertainties in a large population of global-scale carbon-climate models. An integrating theme across these three regional focus areas is the use of observations and experimental results to evaluate model performance. This effort will result in an improved model evaluation framework, building on the success of the existing Carbon-Land Model Intercomparison Project (C-LAMP). We will add new observations and metrics to C-LAMP and use this system to test hypotheses related to the causes of variation among carbon-climate models.

SIGNIFICANCE

There is broad agreement in the scientific community that changes in climate over the next several centuries will depend in part on anthropogenic emissions of carbon dioxide and other greenhouse gases due to the direct influence of GHG concentrations on atmospheric radiative forcing. It is also well-understood that prediction of anthropogenically-forced climate change is complicated by the existence of multiple climate system feedback loops connecting atmospheric GHG levels to physical and biological processes on land and in the oceans. We have prioritized our efforts to focus on three of the most significant terrestrial ecosystem types, in terms of their contributions to the global carbon cycle, categorized by latitudinal zones: 1) tropical upland and lowland forests, with a focus on carbon-nutrient interactions, 2) forests of the temperate zone, with a focus on the consequences of land use modification and age-class dynamics over the past several centuries, and 3) high-latitude forest, shrub, and tundra ecosystems, with a focus on permafrost dynamics and related changes. In each of these zones and ecosystem types, the CMIP5 model representations of carbon cycle-climate interactions, as well as interactions with water and nutrient cycles, are limited at present by an incomplete understanding of the relevant processes and inadequate comparison with available observations and experiments. Our project aims to overcome these limitations to deliver model predictions with reduced carbon-climate feedback uncertainties, as well as to provide an improved framework for evaluating the performance of carbon-climate models participating in CMIP5. Our goal is to reduce the range of climate prediction uncertainty by improving the representation of key terrestrial ecosystem processes that regulate feedbacks and by identifying model predictions that are inconsistent with available observations and experimental results.

Impacts, Adaptation and Vulnerability Science

The IAV research theme represents the gateway to a broad range of ORNL capabilities and knowledge relevant to understand the societal and ecological consequences of climate change and is, therefore, a critical vehicle for translating research achievements in the other CCSI research themes into policy relevant insights that inform decision-making on adaptation and mitigation. The theme places particular focus on four sub-domains: characterization of climate extremes, assessment of the impacts of climate change to human settlements and supporting systems (i.e. energy, transportation, and water), human and national security, and ecosystem services and sustainability. Focuses within the Impacts, Adaptation, and Vulnerability Science theme include:

- Climate Change Consequences
- Decision Support Frameworks
- Linkages to Energy Infrastructures
- Mitigation/Adaptation Scenarios
- Adaptation in Ecosystems

Assistance with Incorporating Impacts into Integrated Assessment

PI: Thomas J. Wilbanks

PARTICIPATING STAFF: Sherry B. Wright

Project Start Date: May 14, 2007

Project End Date: December 31, 2011

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Pacific Northwest National Laboratory (PNNL), Massachusetts Institute of Technology (MIT)

PROJECT DESCRIPTION

The Assistance with Incorporating Impacts into Integrated Assessment project is intended to explore scientific needs and issues related to climate change energy impacts and the role of energy in climate change impact adaptation. This will include efforts to better understand the (a) interface between mitigation and adaptation responses and (b) issues with energy and water resources. Efforts may include providing scientific and technical support in conducting technical workshops, bringing experts together to explore technical/research/modeling approaches, and challenging the Integrated Assessment research community with ideas and concepts that move the field toward increased representation of energy impacts in integrated assessment models (IAMs), working closely with PNNL, MIT, and other modeling teams. This project will assist DOE in its roles in supporting the development of the next US National Assessment of Consequences of Climate Change.

SIGNIFICANCE

Climate change science is a combination of (a) climate science/earth system modeling (CM/ESM), (b) integrated assessment modeling (IAM), and (c) impact, adaptation, and vulnerability analysis. IAM develops scenarios of greenhouse gas emissions as a function of economic and energy technology driving forces, which are then used by CM/ESM as starting points for climate change scenarios. The third loop is to convert the climate change scenarios into impacts and adaptive responses, especially where those impacts and responses would in turn shape energy production and use. This project assists DOE and the IAM community in improving the capacity to close this third loop, emphasizing energy sector impacts and adaptations, along with linkages between the energy sector and impacts and adaptations in the water and land use sectors.

Developing a Regional Integrated Assessment Model (RIAM) Framework

PRINCIPAL INVESTIGATOR: Benjamin L. Preston

PARTICIPATING STAFF: Auroop R. Ganguly, Anthony W. King, Wilfred M. Post, Thomas J. Wilbanks

PROJECT START DATE: July 1, 2010

PROJECT END DATE: June 30, 2015

SPONSOR: US DOE, Office of Science, Office of Biological and Environmental Research (BER)

PARTNERS: Pacific Northwest National Laboratory

PROJECT DESCRIPTION

Integrated assessment models (IAMs) are one of the key tools for examining the interactions between biophysical responses of the Earth system to climate change and the associated economic responses of human systems. This project seeks to apply a regional IAM framework to the Gulf Coast region of the United States—a region where climate impacts and adaptation, agriculture and land use issues, coastal issues, and energy supply issues are all occurring simultaneously, but for which integrated modeling has not been seriously attempted.

The selected IAM framework is based upon the Global Change Assessment Model (GCAM), developed by Pacific Northwest National Laboratory (PNNL), which is being regionalized to develop a new regional IAM capability (Regional Global Change Assessment Model [RCGAM]). RCGAM will use the newly developed representative concentration pathways (RCPs) to drive global climate simulations with the Community Climate System Model (CCSM). Regional climate scenarios for the Gulf Coast will be developed by downscaling CCSM results using the Weather Research and Forecasting regional climate model coupled to the Regional Ocean Model Systemocean model. Additional modeling of the coastal zone, including the effects of sea-level rise and storms on coastal inundation, will be undertaken with the Finite Volume Community Ocean Model coastal ocean circulation model. This biophysical information will be applied in impacts models coupled with RGCAM to assess climate change impacts at the land-water-energy nexus. A range of mitigation and adaptation experiments subsequently will be applied to RGCAM to test the costs, benefits, and trade-offs associated with different policy options for addressing the risks of climate change.

In developing and applying RGCAM for the Gulf Coast region, there are four key research questions for which it is hoped new insights will be gained:

1) What are the regional characteristics and opportunities for mitigation and adaptation strategies? For example, are there physical or economic constraints that make the implementation of different energy technologies or mitigation strategies more difficult, but that are only appreciated when simulations are done with greater regional specificity than the national or international strategies that are done today?
2) How do changes in mean climate and climate variability affect adaptation and mitigation strategies?
3) What are the interactions between management decisions and natural processes that contribute to rapid, or nonlinear changes in the environment? Where are such nonlinearities, and how do their consequences contribute to climate feedbacks?
4) How will adaptation and mitigation strategies interact in the next few decades?

SIGNIFICANCE

While IAMs have been in development and use for a number of years, such models have largely targeted large aggregate geographic regions, and thus, regionalized approaches to such modeling are largely unexplored. Yet, increasingly, decision-makers seek insights regarding the implications of climate change and policy responses at more refined scales. Therein lies the utility of developing IAMs for regional applications. In developing such approaches, one of the main objectives is to understand the implications of such integrated modeling at regional scales and how the insights that such models might provide differ from insights derived from models at coarser scales with national or international domains.

General Questions:
climatescience@ornl.gov
Phone: 865-574-5435
Fax: 865-574-6476

Technical Questions:
James Hack (jhack@ornl.gov)
Giri Palanisamy (palanisamyg@ornl.gov)
Peter Thornton (thorntonpe@ornl.gov)
Ben Preston (prestonbl@ornl.gov)