BOOK OF ABSTRACTS

The U.S. North American Carbon Program (NACP) Investigators

and

Joint Canada-Mexico-USA Carbon Program Planning Meetings

January 22-26, 2007
Colorado Springs, Colorado USA

About this Book

This Book of Abstracts contains the poster abstracts scheduled to be presented at the U.S. North American Carbon Program (NACP) Investigators and Joint Canada-Mexico-USA Carbon Program Planning Meetings, January 22-26, 2007.

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I.10 **North America Terrestrial Carbon Budget: A Model Analysis of the Combined Effects of CO2, Nitrogen, Climate, Land Use Changes and Management** (*Atul Jain*, Xiaojuan Yang, Wilfred Post)

I.11 **The National Biomass and Carbon Dataset 2000: A high-resolution baseline of conterminuous U.S. Biomass and Carbon Stocks from InSAR/Optical Fusion** (Josef M Kellndorfer, *Wayne S Walker*, Jesse Bishop, Elizabeth LaPoint, Michael Hoppus, James Westfall)

I.12 **Sampling for national-level estimates of trends in forest disturbance and regrowth** (*Robert E Kennedy*, Warren B Cohen, Gretchen G Moisen, Samuel N Goward, Michael Wulder, Scott L Powell, Jeffrey G Masek, Chengquan Huang, Sean P Healey)

I.13 **Mapping Incident Photosynthetically Active Radiation over North America** (*Shunlin Liang*, Tao Zheng, Dongdong Wang, Kaicun Wang, Steve Running, John Townshend, Si-chee Tsay)

I.14 **Developing the Improved Land Surface Biogeophysical Products over North America** (*Shunlin Liang*, Hongliang Fang, John Townshend, Robert Dickinson)

I.15 **Constraining North American Fluxes of Carbon Dioxide and Inferring their Spatiotemporal Covariances through Assimilation of Remote Sensing and Atmospheric Data in a Geostatistical Framework** (*Anna M Michalak*, Adam I Hirsch, John C Lin, Arlyn Andrews)

I.16 **Perpetual Growth, or Potential Catastrophic Dieback of North American Forests?** (*Ronald P. Neilson*, Dominique Bachelet, James M Lenihan, Raymond J Drapek, F Ian Woodward, Mark R Lomas, David Price)

I.17 **Terrestrial ecosystem nowcasts and forecasts for North America** (*Ramakrishna R. Nemani*, Jennifer L. Dungan, Hirofumi Hashimoto, Kazuhito Ichii, Andrew Michaelis, Cristina Milesi, Petr Votava, Michael A. White)

I.18 **Forest FACE Synthesis Project: Net Primary Productivity** (*Richard J Norby*, Joanne Ledford, Evan H DeLucia, David J P Moore, Ram Oren, Heather R McCarthy, Birgit Gielen, Carlo Calfapietra, Christian P Giardina, John S King)

I.19 **Canopy Nitrogen and Carbon Assimilation Across a Network of NACP - AmeriFlux Sites** (*Scott Ollinger*, Marie-Louise Smith, Mary Martin, Lucie Plourde, Andrew Richardson, Julian Jenkins, David Hollinger)

I.20 **Sensitivity of carbon dioxide fluxes to soil moisture in a coupled regional model** (*Zaitao Pan*, Lulin Xue, Moti Segal, Eugene Takle)

I.21 **Terrestrial Carbon Sinks for the United States Predicted from MODIS Satellite Data and Ecosystem Modeling** (*Christopher Potter*, Steven Klooster, Alfredo Huete, Vanessa Genovese)

I.22 **Innovative uses of MODIS data to assess gross primary productivity and respiration of North American ecosystems** (*Abdullah Faizur Rahman*, Daniel Arthur Sims)

I.23 **Climate impacts of North American carbon sinks** (*James T. Randerson*, Yufang Jin, Heping Liu, Michael L. Goulden)

I.24 **Historical Influence of Soil and Water Management on Carbon Erosion and Burial in the United States** (*Eric T. Sundquist*, Katherine Visser Ackerman, Robert F. Stallard, Shuguang Liu, Norman B. Bliss)

I.25 **Comparison of Two U.S. Power-Plant Carbon Dioxide Emissions Datasets** (Katherine Visser Ackerman, *Eric T. Sundquist*)

I.26 **A high-resolution daily surface weather database for NACP investigations** (*Peter E Thornton*, Robert B. Cook, W. Mac Post, Bruce E. Wilson, Craig Hartsough)

I.27 **The human carbon budget: the spatial distribution of carbon consumption and release in the US** (*Tristram O West*, Nagendra Singh, *Gregg Marland*, Budhendra L Bhaduri, Adam B Roddy)

I.28 **A One-Dimensional Study of Cumulus Convection in the Diurnal and Seasonal Atmospheric CO_2 Budgets Over the Southern Great Plains** (*Ian N Williams*, William J Riley, Joseph A Berry, Margaret S Torn, Marc L Fischer)

I.29 **The 1998-2002 North American drought and the anomalous CO2 growth in 2002-2003** (*Ning Zeng*, Haifeng Qian, Christian Roedenbeck, Martin Heimann)

I.30 **Can remotely sensed canopy heights be used to improve MODIS-based estimates of ecosystem carbon balance?** (*Joost van Haren*, Michael Goulden, Pathmathevan Mahadevan, Steve Wofsy, Scott Saleska)

I.37 **An integrated carbon model (ITCM) for North America: Constraining process models with experiments and measurements for analysis and projection.** (*Wilfred Post*, Anthony King, Lianhong Gu, Forrest Hoffman, Chris Kucharik, William Parton, Margaret Torn, Douglas Miller)

I.38 **Towards Robust Carbon Budget Estimates for North America** (*J. Eluszkiewicz*, T. Nehrkorn, S. Wofsy, P. Mahadevan, D. Matross, M. Longo, J. Lin, C. Gerbig, S. Freitas)

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Carbon Management and Decision Support

J.1 **Linking Landscape-Scale Carbon Monitoring with Forest Management** (*Richard Birdsey*, Michael Ryan, Marie Louise-Smith, Randall Kolka, Steven McNulty, John Hom, Chris Potter, Michael Lefsky, John Bradford, Peter Weishampel)

J.2 **Recursive Calibration of Ecosystem Models Using Sequential Data Assimilation** (*Mingshi Chen*, *Shuguang Liu*, *Larry L. Tieszen*)

J.3 **Trends and Uncertainties of Regional Carbon Stocks and Fluxes in the United States: Upscaling From Sites Using Data Assimilation** (*Shuguang Liu*, Zhenpeng Li, *Mingshi Chen*, Zhengxi Tan, *Larry L. Tieszen*, Thomas R. Loveland)

J.4 **Net primary production in the Mid-Continent region: comparison of two models versus surveys at the county scale** (*Richard T Conant*, Christopher S Potter, Stephen A Klooster, Stephen Williams, Keith Paustian, Stephen M Ogle)

J.5 **Soil Carbon Sequestration in the U.S. Corn Belt** (*Paul C Doraiswamy*, Hector Causarano, Craig Daughtry, Gregory McCarty, Jerry Hatfield)

J.6 **Coupling Biogeochemical and life cycle greenhouse gas (GHG) models to manage GHG budgets of the biological and industrial system** (*Stith Thompson Gower*, Douglas E. Ahl)

J.7 **SOCCR: The State of the Carbon Cycle Report; U.S. Climate Change Science Program Synthesis and Assessment Product 2.2** (*Anthony King*, Lisa Dilling)

J.8 **Decision Support Tools and Data Analysis for Ecosystem Carbon Management in the United States** (*Christopher Potter*, Vanessa Genovese, Peggy Gross, Seth Hiatt, Steven Klooster)

J.9 **Economic Potential for Carbon Sequestration through Afforestation of Agricultural Lands in the Northeast States** (Sarah Walker, *Timothy Pearson*, Sean Grimland, Jonathon Winsten, Sandra Brown)

J.10 **Carbon Management in Intensively Managed Loblolly Pine Plantations** (*Randolph H. Wynne*, Christopher S. Potter, John R. Seiler, David A. Samspon, Thomas R. Fox)

Reconciling Top-Down and Bottom-Up Approaches to Estimating Carbon Fluxes

K.1 **Top-down constraints on carbon dioxide surface fluxes with carbonyl sulfide observations** (*John Elliott Campbell*, Tianfeng Chai, Gregory Carmichael, Nicola Blake, Stephanie Vay, Yonghoon Choi, Jerald Schnoor, Charles Stanier)

K.2 **Landscape-level Carbon Flux Estimates from CO2 Concentration Measurements on Flux Towers and Remote Sensing-based Footprint Integration** (*Jing M. Chen*, Baozhang Chen, Gang Mo, Doug Worthy)

K.3 **Using auxiliary environmental data to constrain global carbon fluxes within a geostatistical inverse modeling framework** (*Sharon M Gourdji*, Kimberly L Mueller, Anna M Michalak)

K.4 **Techniques in scaling ecosystem carbon flux from landscape studies to broad scale remote sensing.** (*Julian P Jenkins*, Scott V Ollinger, Mary E Martin, Andrew D Richardson, Lucie C Plurde, Bobby H Braswell, Marie-Louise Smith, David Y Hollinger)

K.5 **Progress in Modeling Global Atmospheric CO2 Fluxes and Transport** (*S Randy Kawa*, G Jim Collatz, A Scott Denning, David Erickson)

K.6 **Carbon Flux Super Site** (*Monique Y Leclerc*, Matt Parker, Roni Avissar, Tom Watson, Arlyn Andrews, William Eichinger, Paul Bertsch)

K.7 **Fuel Loading and Consumption Models for Assessing Carbon Release from Wildland Fires** (*Donald McKenzie*, Roger D Ottmar, David V Sandberg)

K.8 **Contribution of Ocean, Fossil Fuel, Land Biosphere and Biomass Burning Carbon Fluxes to Seasonal and Interannual Variability in Atmospheric CO2** (*Cynthia D Nevison*, Natalie M Mahowald, Scott C Doney, Ivan D Lima, James T Randerson, Galen McKinley, David F Baker)

K.9 **Carbon cycle data assimilation to improve terrestrial carbon flux diagnosis and prediction** (*Daniel M. Ricciuto*, Klaus Keller, *Kenneth J. Davis*, Ankur R. Desai, A. Scott Denning)

K.10 **Uncertainty estimates for prognostic modeling of terrestrial carbon cycle at continental to global scales.** (*Peter E Thornton*, Bob Cook, Wilfred Post, Bruce Wilson)

K.11 **Regional Flux Intercomparison in the Southern Great Plains during the 2007 NACP Mid Continent Intensive: an invitation to participate** (*Margaret S Torn*, Marc L. Fischer, William J Riley, Tom J Jackson, Roni Avissar, Sebastien C Biraud, David P Billesbach, Colm Sweeney, Pieter Tans, Joseph A Berry)

K.12 **New constraints on Northern Hemisphere growing season net flux** (Zhonghua Yang, Rebecca A. Washenfelder, Gretcher Keppel-Aleks, *Paul O Wennberg*, N. Y. Krakauer, J. T. Randerson)

K.13 **Tropospheric CO interannual variations: a way to estimate gaseous emissions from boreal forest fires.** (*Leonid Yurganov*, Wallace McMillan, Anatoly Dzhola, Evgeny Grechko)

K.14 **Maximum Likelihood Ensemble Filter (MLEF) approach to carbon data assimilation** (*Dusanka Zupanski*, Scott Denning, Marek Uliasz, Milija Zupanski)

Integrating Social Science and Economics into NACP

L.1 **Spatial Distribution and Density of Constructed Impervious Surface Areas in North America** (Christopher D. Elvidge, *Benjamin T. Tuttle*, Kimberly E. Baugh, Milesi Milesi, Ramakrishna Nemani, Paul Sutton)

Data Systems/Management

M.1 **NACP Data Center for Modeling and Synthesis** (*Robert B. Cook*, Wilfred M. Post, Bruce E. Wilson, Peter E. Thornton)

M.2 **Enhancing Linkages Between Projects and Datasets: Examples from LBA-ECO for NACP** (Lisa Wilcox, *Amy L. Morrell*, Peter C. Griffith)

M.3 **NACP Project Profiles: Enhancing communication among scientists and agency managers** (Lisa Wilcox, *Amy L. Morrell*, Peter C. Griffith)

Thursday, January 25

Atmospheric Measurements and Analyses

A.2 **Measuring CO_2 Fluxes from Space: The NASA Orbiting Carbon Observatory (OCO)** (*David Crisp*)

A.12 **Estimating local, regional and continental fluxes from the NOAA/ESRL aircraft networ** (*Colm Sweeney*, Pieter Tans, Cyril Crevoisier, Wouter Peters, Adam Hirsch, Anna Font)

A.15 **A Nested Global Inversion System With a Focus on North America: Comparison With 1992-2003 Bottom-up Results in Canada** (*Jing M Chen*, Feng Deng, Weimin Ju, Misa Ishizawa, Ken Yuen, Gang Mo, Kaz HIguchi, Douglas Chan)

A.16 **Mesoscale Carbon Data Assimilation for NACP** (*Scott Denning*, Dusanka Zupanski, Marek Uliasz, Kathy Corbin, Andrew Schuh)

A.17 **An evaluation of the uncertainties of CO2 and sensible heat flux measurements from a light aircraft platform and comparison to tower-based measurements** (*Douglas K Martins*, Karl E Garman, Paul B Shepson, Michael Jacox, James Smith, Michael Hahn, Steven Garrity, Lee Vierling, Robert Santini, Phillip Wyss, Mike Everly, Mark Carlsen, Jim Zimmerman, Brian Stirm, Hans Peter Schmid, Chris Vogel)

A.18 **Airborne CO2 Flux Measurement at the National Research Council of Canada** (*Ramesh Srinivasan*, Dave Marcotte, Anthony Brown)

A.19 **Ground- and space-based spectrometers for monitoring biomass burning emissions** (*Leonid Yurganov*, Wallace McMillan)

Terrestrial and Riverine Measurements and Inventories, including Flux Measurements

B.3 **Mapping Carbon Pools in the Southwestern US** (*Mark Chopping*, Gretchen Moisen, Lihong Su, Albert Rango, Andrea Laliberte, John Martonchick, Debra Peters)

B.5 **Modeling variability in biomass consumption for estimating fire emissions** (*Nancy HF French*, Richard B. Powell, Lucas Spaete, Bejamin W. Koziol, Luz Silverio, Eric Kasischke, William de Groot, Ron Hall, Roger Ottmar)

B.19 **Carbon Cycling in Mature and Harvested Black Spruce Forests in Eastern Canada** (Onil Bergeron, *Hank A Margolis*, Marc-Andre Giasson, Carole Coursolle)

B.21 **Quantifying the carbon budget of developed land use in North America** (*Joseph P McFadden*, Marvin E Bauer, Jindong Wu, Ahmed A Balogun, Emily B Peters)

B.24 **Trends in CO2 Exchange at Harvard Forest** (*J. William Munger*, Shawn P. Urbanski, Carol Barford, Steven C. Wofsy, Chris Kucharik, Elizabeth Hammond-Pyle, John Budney, Kathryn McKain, Neil Pederson, Dave Fitzjarrald)

B.41 **Carbon stocks in primary and secondary tropical forests of Mexico** (*Victor J. Jaramillo*, Angelina Martinez-Yrizar, J. Boone Kauffman, Luz Piedad Romero-Duque, Felipe García-Oliva)

B.42 **Opportunities for carbon sequestration and conservation in semiarid rangelands and grazing lands over the Mexico - USA border** (Mario G. Manzano, Oscar Infante)

B.43 **Long-wavelength flux contributions as reason for the underestimation of conventional tower-based eddy-covariance measurements** (*Matthias Mauder*, Raymond L. Desjardins, Ian MacPherson)

B.44 **Carbon stocks and emissions dynamics, derived from land use change process in the Highlands in Central Mexico, for 1986-2000.** (*Jose Antonio Benjamin Ordóñez*, Omar Masera, Felipe García-Oliva, Ben de Jong)

B.45 **Modelling the Impacts of Reservoirs and Forest Harvesting on the Carbon Budget of Aquatic Ecosystems in Quebec, Canada** (*Changhui Peng*, Haibin Wu, Marc Lucotte, Nicolas Soumis, Eric Duchemin, Yves Gélinas)

B.46 **Response of surface fluxes at a Tropical Deciduous Forest site in northern Mexico to the North American Monsoon (NAM)system.** (*Christopher J Watts*, Jaime Garatuza-Payan, Julio Cesar Rodriguez)

B.47 **Novel Non-Destructive Soil Carbon Analysis; II - Characteristics and Results** (*Lucian Wielopolski*)

B.48 **Impact of land use and land-use change on CO2 emissions in Mexico** (*Bernardus H.J. de Jong*, Marcela Itzel Olguin-Alvarez, Omar Masera-Cerutti, Carlos Anaya, René Martínez, Jorge Etchevers, Claudio Balbontin, Fernando Paz, Gabriela Guerrero, Myrna Motolinia)

Coastal and Oceanic Measurements

C.1 **A preliminary synthesis of air-sea CO_2 flux and an exploration of control mechanisms in the US east coast and other western boundary current shelves** (*Wei-Jun Cai*)

C.2 **Air-sea CO_2 flux and carbon budget in the Gulf of Mexico: State of knowledge and research initiatives in North America's largest marginal sea** (*Wei-Jun Cai*, Steven E Lohrenz, Rik H Wanninkhof)

C.4 **Carbon Sources and Sinks in the Mexican Pacific Coastal Waters** (*Rubén Lara-Lara*, Martin Hernández-Ayón)

C.9 **High frequency CO_2 variability in North American coastal waters** (*Christopher L. Sabine*, Don Conlee, Doug Vandemark, Wei-Jun Cai, Burke Hales, Stacy Maenner)

C.15 **Temporal and spatial variation of air-sea CO2 fluxes in the West Coast of Baja California, Mexico.** (*Jose(Martin) Martin Hernandez-Ayon*, Ruben Lara, Francisco Chavez, Taro Takahashi, Gilberto Gaxiola)

Mid-Continent Intensive Study

D.3 **Investigation of Carbon Cycle Processes within a Managed Landscape: Recent Progress and Future Research** (*Timothy Griffis*, John Baker)

D.6 **Carbon Sequestration Potential in Midwest Agricultural Land and Restored Grasslands (Fermiflux) study** (*Roser Matamala*, David R. Cook, Scott L. Graham, Julie D. Jastrow)

D.8 **The Bondville Intensive: An Integrated, Bottom-Up Approach to Estimating Regional Fluxes** (*Derek Williamson*, Carl Bernacchi, Tilden Meyers)

Managed Forests and Woodlands

E.10 **Carbon sequestration project, from integral management of the common resources options, for indigenous and rural communities in Oaxaca, Mexico.** (*Carlos Marcelo Pérez-González*, Elizabeth Rodríguez-Rojas, Fermín Rafael de la Rosa-Pablo)

E.11 **A Modelling Framework for Carbon Stock and Sequestration at Regional Scales and Scenarios of Synergistic Co-Benefits Through Land Use Changes in Agricultural and Forested Lands** (Raul Ponce-Hernandez)

Arctic and Boreal Ecosystems

F.4 **Carbon Fluxes From Canadian Forests and Peatlands: the Fluxnet-Canada Perspective** (Carole Coursolle, *Hank Margolis*, Science Committee Members)

F.5 **Characterization of frozen and thawed seasons in the terrestrial high latitudes with spaceborne microwave remote sensing: Relationships with land-atmosphere CO2 exchange** (*Kyle C McDonald*, John S Kimball)

F.9 **Progress and Prospects at the Boreal Ecosystem Research and Monitoring Sites** (*Alan G. Barr*, T. Andy Black, J. Harry McCaughey, Brian Amiro, Ted Hogg, Zoran Nesic, Praveena Krishnan)

F.10 **Interannual to decadal changes in area burned in Canada from 1781-1982 and the relationship to Northern Hemisphere land temperatures** (*Martin Philippe Girardin*)

F.11 **The impacts of North American boreal fires on terrestrial carbon cycling and atmospheric trace gas concentrations** (*Eric S. Kasischke*, William DeGroot, Merritt R. Turetsky, A. David McGuire, James T. Randerson, Jennifer Harden, Roger Ottmar)

F.12 **Using knowledge of environmental control of the onset of photosynthesis to predict the impact of global warming on springtime carbon uptake by northern forests** (*Michael B Lavigne*, Pierre Y Bernier, Rodney J Foster)

F.13 **Simulating Dissolved Organic Carbon Dynamics in Boreal Forests** (Dong Hua, *Changhui Peng*, Tim Moore, Jiangfeng Sun)

F.14 **Assessing the vulnerability of boreal peatlands to changing climate and fire regimes** (*Merritt R. Turetsky*, Brian Amiro, Bill DeGroot, Mike Flannigan, Nancy French, Jennifer Harden, Eric Kasischke, A. David McGuire, Jim Randerson)

F.15 **Impacts of Soil Freeze/Thaw Dynamics on the North American Carbon Cycle** (*Tingjun Zhang*, Lixin Lu, Kevin Schaefer, Scott Denning)

Integrating Land, Coastal Margins, and Oceans

G.1 **A large knowledge gap in the NACP: The role of intertidal marshes in the transfer of CO_2 between the atmosphere and the ocean** (*Wei-Jun Cai*)

Regional Analyses

H.3 **The ORCA West Coast Regional Project: Ground measurements made across key vegetation gradients** (*John Campbell*, Beverly Law)

H.7 **A multiple constraints model-data assimilation scheme to combine MODIS thermal and AMSR-E microwave image products for estimation of land surface variables and fluxes in tropical savannas** (Luigi J Renzullo, Damian J Barrett, Alan S Marks, *Michael J Hill*, Juan P Guerschman, Qiaozhen Mu, Steven W Running)

H.8 **Quantifying surface fractional cover using remote sensing for improving land surface schemes of water and carbon fluxes in tropical savannas** (Juan P Guerschman, *Michael J Hill*, Damian J Barrett, Luigi J Renzullo, A Alex Held)

H.9 **Markov chain Monte Carlo: Practical Aspects of its Application to Terrestrial C-Cycle Model-Data Assimilation** (Luigi J Renzullo, Damian J Barrett, *Michael J Hill*)

H.12 **The ORCA West Coast Regional Project - Use of Top-Down Modeling in a Regional Carbon Budget Approach to Estimate Gross Carbon Fluxes for Oregon-California** (*Mathias Goeckede*, Julie M Styles, *Beverly E Law*)

H.15 **An Analysis of Regional Carbon Stocks Estimates Using Airborne and Spaceborne Lidar in Quebec** (Boudreau Jonathan, Nelson F. Ross, Kimes S. Dan, Beaudoin Andre, *Hank A. Margolis*)

H.20 **Modeling Complex Effects of Multiple Environmental Stresses on Carbon Dynamics of Mid-Atlantic Temperate Forests** (*Yude Pan*, Richard Birdsey, John Hom, Kevin McGullough)

H.24 **Distribution of Aboveground Carbon Stock in North American Forests** (*Sassan Saatchi*, Ranga Myneni, Linda Heath, Yifan Yu, Yuri Knyazikhin, Elizabeth LaPoint, Alessandro Baccini)

H.29 **Carbon Content and Changes in Soils of the Forestry Sector of Mexico** (*Jorge D. Etchevers*, Claudio Balbontín, Fernando Paz, Ben de Jong, Omar Masera)

H.30 **Simulating carbon balance in US agroecosystems under present and future climates** (*Roberto C. Izaurralde*, Allison M. Thomson, Steve R. Potter, Jay D. Atwood, Jimmy R, Williams)

H.31 **ORCA West Coast Regional Analysis** (*Beverly E. Law*, David Turner, Warren Cohen, Mathias Goeckede, John Campbell, Maureen Duane, Tara Hudiburg, Dave Ritts, Zhiqiang Yang)

H.32 **Evolution of carbon pools and emissions from land use change process in the Huahutlas´s Sierra in Morelos, Mexico.** (*María de Jesús Ordóñez*, Paulin Mur, Quirin Oberpriller, *José Antonio Benjamín Ordóñez*)

Continental Carbon Budgets and Analyses

I.21 **Terrestrial Carbon Sinks for the United States Predicted from MODIS Satellite Data and Ecosystem Modeling** (*Christopher Potter*, Steven Klooster, Alfredo Huete, Vanessa Genovese)

I.31 **Progress Toward Monthly Resolution Fossil-Fuel-Derived Carbon Dioxide Emissions for the Countries of the North American Carbon Program** (*Robert J Andres*, Jay S Gregg, London M Losey, Gregg Marland, Tom A Boden)

I.32 **Estimating forest properties across large landscapes in the Canadian Boreal Forest** (André Beaudoin, *Pierre Bernier*, Louis Degrandpré, Sylvie Gauthier, David Paré, Huor Ung)

I.33 **Variations in Global Terrestrial Primary Production and Evapotranspiration Observed by the Moderate Resolution Imaging Spectroradiometer (MODIS), 2000-2005** (*Faith Ann Heinsch*, Maoshen Zhao, Qiaozhen Mu, Steven W Running)

I.34 **Global Representativeness of the AmeriFlux and Fluxnet Networks** (William W Hargrove, *Forrest M Hoffman*)

I.35 **Perpetual Growth or Potential Catastrophic Dieback of North American Forests?** (*Ronald P Neilson*, Dominique Bachelet, James M Lenihan, Raymond J Drapek, F Ian Woodward, Mark R Lomas, David Price)

I.36 **A high-resolution daily surface weather database for NACP investigations** (*Peter E Thornton*, Robert B. Cook, W. Mac Post, Bruce E. Wilson, Craig Hartsough)

Carbon Management and Decision Support

J.1 **Linking Landscape-Scale Carbon Monitoring with Forest Management** (*Richard Birdsey*, Michael Ryan, Marie Louise-Smith, Randall Kolka, Steven McNulty, John Hom, Chris Potter, Michael Lefsky, John Bradford, Peter Weishampel)

J.7 **SOCCR: The State of the Carbon Cycle Report; U.S. Climate Change Science Program Synthesis and Assessment Product 2.2** (*Anthony King*, Lisa Dilling)

J.8 **Decision Support Tools and Data Analysis for Ecosystem Carbon Management in the United States** (*Christopher Potter*, Vanessa Genovese, Peggy Gross, Seth Hiatt, Steven Klooster)

J.11 **Particularities of urbanization, sustainability and carbon emissions in Latin American cities** (*Patricia Romero Lankao*)

Reconciling Top-Down and Bottom-Up Approaches to Estimating Carbon Fluxes

K.15 **Tracking the Carbon Oxidation State and Oxidative Ratio of the Terrestrial Biosphere** (*Caroline A Masiello*, William C Hockaday, Morgan E Gallagher, James T Randerson, Oliver A Chadwick, Jeff A Baldock, Ronald J Smernik)

K.16 **Constraining North American Fluxes of Carbon Dioxide and Inferring their Spatiotemporal Covariances through Assimilation of Remote Sensing and Atmospheric Data in a Geostatistical Framework** (*Anna M Michalak*, Adam I Hirsch, John C Lin, Arlyn Andrews)

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Monday, January 22

Atmospheric Measurements and Analyses

A.1: Making use of surface layer and ABL concentration measurements for regional flux analysis

Adam Wolf, Carnegie Institution, adamwolf@stanford.edu
Adam Hirsch, NOAA/GMD,, Adam.Hirsch@noaa.gov
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Joe Berry, Carnegie Institution, joeberry@stanford.edu (Presenting)

Frequent, well-calibrated measurements of trace gas concentrations can be routinely obtained from a number of sites around the world and the technology exists to greatly expand both the number of such sites and the range of species being measured. CO_2, CO, CH_4, COS, ^{222}Rn and the isotopes of CO_2 seem to hold great promise for providing information about biospheric fluxes and for unraveling these from anthropogenic fluxes. The central problem holding back the exploitation of these data is that we don't know what to compare these measurements to. In the laboratory, a flux measurement requires knowledge of two concentrations, that going into and out of the cuvette,and a flowate. By analogy, we need essentially the same information to interpret atmospheric measurements. However, this is a much more complex problem. At any time there may be substantial gradients in the trace gas composition of the atmosphere, and synoptic systems mix air from different sources upwind of the measurement sites. To address these problems, we are exploring the use of FLEXPART, an atmospheric particle dispersion model together with simulations of CO_2 variation of the global atmosphere driven by assimilated winds and weather. This approach will be compared to flux estimates obtained earlier by a simple 1-dimensional method based on the vertical gradients of CO_2 and water vapor or modeled ^{222}Rn.

A.2: Measuring CO_2 Fluxes from Space: The NASA Orbiting Carbon Observatory (OCO)

David Crisp, Jet Propulsion Laboratory, California Institute of Technology, David.Crisp@jpl.nasa.gov (Presenting)

The Orbiting Carbon Observatory (OCO) will make global, space-based measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize CO_2 sources and sinks on regional scales and quantify their vari¬ability over the seasonal cycle. This NASA Earth System Science Pathfinder (ESSP) mission will be launched from Vandenberg Air Force Base in late 2008. It will fly in a 705 km altitude, sun-synchronous (1:26 PM) near polar orbit (98.2 degree inclination) that provides global coverage of the sunlit hemisphere with a 16-day round track repeat cycle. OCO carries a single instrument, which incorporates 3 high resolution grating spectrometers that will make coincident measurements of reflected sunlight in near-infrared CO_2 and molecular oxygen (O_2) bands. These measurements will be analyzed with a remote sensing retrieval algorithm to provide spatially resolved estimates of the column-averaged CO_2 dry air mole fraction, XCO_2. The instrument collects 200 to 400 soundings per degree of latitude over the sunlit portion of the orbit. After screening for clouds and aerosols, the remaining data is expected to yield XCO_2 estimates with accuracies of ~0.3 to 0.5% (1 to 2 ppm) on regional scales every month. These measurements will be analyzed with source/sink inversion and data assimilation models to infer CO_2 surface fluxes. These results are expected to improve our understanding of the nature and processes that regulate atmospheric CO_2 enabling more reliable forecasts of CO_2 buildup and its impact on climate change.

A.3: Mesoscale Carbon Data Assimilation for NACP

Scott Denning, Colorado State University, denning@atmos.colostate.edu (Presenting)
Dusanka Zupankski, Colorado State University, zupanski@cira.colostate.edu
Marek Uliasz, Colorado State University, marek@atmos.colostate.edu
Kathy Corbin, Marek, kdcorbin@atmos.colostate.edu
Andrew Schuh, Marek, aschuh@atmos.colostate.edu

We are developing a generalized framework for flux estimation from multiple streams of carbon observations, including spectral vegetation and land cover imagery, eddy covariance flux observations, meteorological data, and both in-situ and remotely sensed observations of atmospheric carbon gases. We us Ensemble Data Assimilation (EnsDA) techniques applied to a coupled model of regional meteorology, ecosystem carbon fluxes, and biomass burning (SiB-CASA-RAMS). Terrestrial carbon fluxes over North America due to photosynthesis, autotrophic respiration, decomposition, and fires, and a "residual" time-mean source or sink will be simulated by the model. The EnsDA method does not require the development of an adjoint of the coupled model, but rather applies an optimization method that involves a large ensemble of forward simulations. Unlike previous high-resolution inversions using transport model adjoint methods, we do not assume surface fluxes remain constant on monthly time scales, nor do we treat the transport model as "perfect." Parameters in the forward coupled model are quantitatively estimated.
We present preliminary results using the SiB-RAMS model, including a prototype of the EnsDA system using a greatly simplified version of the transport based on a Lagrangian Particle Dispersion Model (LPDM). Tests using synthetic data allow us to evaluate assumptions about the spatial and temporal covariance of forward model error. Temporal decomposition of CO2 fluxes into high-frequency physiological and slower biogeochemical mechanisms allow much better data constraint. We are also experimenting with optimization of boundary-layer mixing in the transport model.

A.4: A California Greenhouse Gas Emission Measurement Project (CALGEM)

Marc L. Fischer, Lawrence Berkeley National Laboratory, MLFischer@lbl.gov (Presenting) , **William J Riley**, Lawrence Berkeley National Laboratory, WJRiley@lbl.gov , **Adam I Hirsch**, NOAA-ESRL, Adam.Hirsch@noaa.gov , **Pieter Tans**, NOAA-ESRL, Pieter.Tans@noaa.gov

The State of California has made control of GHG emissions a priority. In California, methane and other non-CO2 GHGs are estimated to be a significant fraction (~ 15%) of total GHG forcing, with CH4 contributing the largest share. However, current inventory and model-based estimates of non-CO2 GHG emissions are extremely uncertain (25% to order of magnitude), because many of the factors controlling emissions are poorly quantified.

In response to the need for quantitative estimates, we began a project for the California Energy Commission to design a measurement network and implement initial measurements of atmospheric non-CO2 GHG concentrations from tall towers in California. Network design will include 1) prediction of atmospheric GHGs and related tracer concentrations from multiple sources present in California, and 2) analysis of the expected retrieval performance using different inverse methods. Initially, measurements will include continuous CH4 and 222Rn (and possibly N2O and CO2) on at least one tower, and daily flask sampling by NOAA-ESRL for (CO2, CO, CH4, SF6, and H2) on all towers, with the likely addition of CFCs, HFCs. The data streams from these measurements will be available to other NACP researchers. We expect the data and results from this study to be valuable for characterizing GHG emissions for a portion of the Western United States and hence contributing to NACP goals. We encourage scientists with interests in both co-locating complementary instrumentation (e.g., meteorological or trace gas soundings), and in model-data fusion to contact us regarding research opportunities.

A.5: Developing high precision measurements of $^{14}CO_2$ for carbon cycle studies

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Measurements of ^{14}C in CO_2 have the potential to be a powerful tool for constructing regional budgets of CO_2 sources because different carbon reservoirs have distinct signatures in $\Delta^{14}C$. The utility of $\Delta^{14}CO_2$ in constraining carbon fluxes depends largely on the available measurement precision and a robust characterization of $\Delta^{14}C$ levels in background air. We have developed methods of AMS measurement of ^{14}C in CO_2 at Lawrence Livermore National Laboratory that have improved the measurement uncertainty to better than 2 per mil. These methods have been applied to measure an archive of CO_2 samples from six sampling stations in the Scripps CO_2 network. Here we present several-year time series of $\Delta^{14}CO_2$ at each of these stations. We also present ^{14}C results from an airborne study used to separate biospheric and industrial CO_2 fluxes in Colorado.

A.6: Regional and Local Carbon Flux Information from a Continuous Atmospheric CO2 Network in the Rocky Mountains

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We have established a Regional Atmospheric Continuous CO2 Network in the Rocky Mountains (Rocky RACCOON) to improve our understanding of regional carbon fluxes and to fill key gaps in the North American Carbon Program (NACP). There are strong scientific and societal motivations for determining CO2 exchanges on regional scales. Mountain forests in particular represent a significant potential net CO2 sink in the U.S. and are highly sensitive to land-use practices and climate change. We have developed a new autonomous, inexpensive, and robust CO2 analysis system (AIRCOA) and have deployed these systems at 4 sites: Niwot Ridge (NWR), near Ward, Colorado (August, 2005); Storm Peak Laboratory (SPL) near Steamboat Springs, Colorado (September, 2005); Fraser Experimental Forest (FEF), near Fraser Colorado (August, 2005); and Hidden Peak (HDP), near Snowbird, Utah (April, 2006). We will deploy a fifth site in Northeastern Arizona in early 2007. Measurements of surveillance gas cylinders, and an ongoing intercomparison with flask measurements made by NOAA GMD at Niwot Ridge, show measurement biases of 0.2 ppm or better. Preliminary analysis of CO2 variability at our sites provides valuable information on the usefulness of mountaintop observations in data-assimilation and inverse modeling. Comparisons between our sites and to background sites, along with careful data selection criteria, can give direct regional-scale flux estimates and analysis of the nocturnal CO2 build-ups at FEF provides unique insights into valley-scale respiration rates. We will present results of these preliminary analyses and plans for future integration with the NACP effort.

A.7: Regular Vertical Profile Measurements of Atmospheric CO2 and Related Tracers over a Boreal Forest of Canada: Understanding the Atmosphere & Surface CO2 Exchange on Regional Scales

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To understand CO2 exchange in the planetary boundary layer and estimate CO2 column budget on regional scales over a boreal forest of Canada, in 2005, Environment Canada constructed a small observatory adjacent to a tall tower (~ 100m) in the vicinity of Prince Albert National Park, SK (~54°N, ~105°W) for continuous measurements of CO2, CH4, CO concentrations. In the same year, a collaborative project between EC and ESRL/NOAA for regular vertical profile sampling was initiated at the location, as part of NACP activities. An aircraft, equipped with a NOAA auto-flask-sampler, was chartered to perform quasi-weekly sampling from 6500m to 500m. An EC-type auto- flask-sampler was installed at the tower for sample collections from two levels (95m and 21m) to synchronize aircraft sampling. Multi-species (CO2 CH4, CO, N2O, SF6, delta-13C, delta-18O) have been measured for both aircraft and tower flasks. Here, we will present these measurements obtained from Sept. 2005 to Sept. 2006. For most species, it is shown that there are (1) large vertical gradients, which can be used to derive free-troposphere compositions, in turn, to constrain mean column CO2 budgets (2) obvious seasonal changes in vertical profiles, which are likely due to seasonal changes of surface sources and sinks.

A.8: An evaluation of the uncertainties of CO2 and sensible heat flux measurements from a light aircraft platform and comparison to tower-based measurements

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Fluxes of CO_2 and sensible heat were observed over the Ameriflux site in Pellston, Michigan using a twin-engine Beechcraft Duchess aircraft. Flux measurements were conducted during a series of flight legs approximately 5km in length from 150m above a predominately deciduous forest during the middle of the growing season between June 21 and July 24, 2006. A combination of a 9-hole wind probe, extending from the nose of the aircraft, and a GPS/INS system enabled measurement of the 3-dimensional winds at 50Hz. Dry Mole Fractions of CO_2 were sampled at 8Hz by an NDIR analyzer with negligible sensitivity to aircraft motion. Sensible heat fluxes were measured using a fast, ultra-sensitive thermocouple just below the wind probe. Measurements were conducted at multiple heights over an Ameriflux tower using racetrack and grid patterns to evaluate flux divergence. Fluxes were calculated by eddy covariance of 2Hz data and averaged over sets of flight legs. Analysis of power spectra and cospectra of the wind components and temperature show the predicted inertial subrange energy dissipation at higher frequencies. A propagation of the random and systematic errors of the measurements gives an overall uncertainty of the CO_2 and sensible heat fluxes. We present an evaluation of the sources of errors and the extent to which reliable flux measurements can be made from the piloted airborne platform. The aircraft fluxes are then compared to 30min averaged CO_2 and sensible heat fluxes at the top of the 46m Ameriflux tower. In addition to any random and systematic errors caused by limitations of the instrumentation, differences in flux measurements are assessed based, in part, on vertical flux divergence, nonstationarity, inhomogeneity, and differences in the footprint of the airborne and stationary platforms.

A.9: Geostatistical Analysis of the Spatial Covariance Structure of Modeled Column Average Dry Air Carbon Dioxide Mole Fraction Distributions

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Future satellites, like the Orbiting Carbon Observatory (OCO), are expected to provide measurements of integrated column CO2 concentrations (XCO2) at high spatial and temporal resolutions. These data have the potential of improving the scientific understanding of regional carbon cycle processes and budgets. However, measurement limitations, due to factors such as cloud cover, aerosols, satellite tracks and albedo, will prevent data coverage at certain locations and times. The ability to fill these gabs within precision requirements depends on the spatial and temporal covariance structure of XCO2 at the satellite's measurement scale. Using MATCH/CASA simulated CO2 concentrations, the global seasonal spatial structure of XCO2 was evaluated regionally. The need for spatial and temporal variability in the sampling density of future satellite measurements was demonstrated by using the evaluated spatial structure to calculate the maximum allowable regional sampling interval (ho) required to achieve 0.75ppm XCO2 precision. Furthermore, the effects of model differences and the relatively low resolution of MATCH/CASA simulated XCO2 were assessed by validating the resulting covariance

parameters using the higher resolution PCTM/GEOS-4 global model, the SIB-RAMS regional model, and air campaign point observations. The resulting MATCH/CASA XCO2 spatial variability showed marked seasonality in the overall variance and correlation lengths representing the XCO2 distribution. The comparison with higher resolution model and point data showed good agreement with MATCH/CASA results. Results indicate that the ability to fill satellite measurement gaps changes with location and time, as areas exhibiting higher variability will require denser data to achieve XCO2 coverage within precision requirements.

A.10: Well-calibrated CO2 observations on AmeriFlux towers to constrain the North American CO2 budget: A contribution to the continental atmospheric CO2 observational network

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Our understanding of the North American terrestrial carbon cycle is limited by both a lack of continental atmospheric CO2 data, and by a need for methods to interpret these and other continental data with confidence. In response to this challenge a rapid expansion of the N. American carbon cycle observational network is underway. This expansion includes a network of continuous, continental CO2 mixing ratio observations being collected at a subset of AmeriFlux towers. We will present progress in developing and utilizing this growing observational network. Progress in developing this resource includes instrument development, site installation, calibration and intercalibration efforts, and initiation of a uniform data product. A network of approximately 12 flux towers with well-calibrated CO2 measurements is currently in operation across North America. Many sites have only begun collecting data within the last 1-2 years. Progess in applying these data include proposed methods for interpreting surface layer measurements in atmospheric inversions (the virtual tall towers approach), examination of coherence patterns in continental mixing ratios in response to weather and climate, and application of these mixing ratio measurements in formal atmospheric inversions. Future work will merge these methods with interpretation of flux towers observations of terrestrial carbon fluxes in an effort to create a single coherent diagnosis of North American terrestrial carbon fluxes over a multi-year period.

A.11: Using atmospheric $^{14}CO_2$ measurements for quantification of fossil fuel emissions and evaluation of atmospheric transport.

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$\Delta^{14}C$ is a theoretically ideal tracer for recently added fossil fuel derived CO_2 in the atmosphere because fossil fuel is entirely devoid of ^{14}C due to radioactive decay whereas all other sources of CO_2 to the atmosphere are relatively ^{14}C rich. On the delta scale, the $\Delta^{14}C$ of fossil fuel CO_2 is -1000‰ (= zero ^{14}C content), while the ambient atmospheric value is ~+60‰. Thus, the addition of 1 ppm fossil CO_2 to the current atmospheric CO_2 burden of ~380 ppm will reduce the ambient isotopic signature by ~2.8‰. Working with the Keck accelerator team at UC-Irvine, we have obtained a long-term $\Delta^{14}CO_2$ measurement precision of 1.8‰ (1-sigma), providing for sub-ppm detection of fossil fuel CO_2. We will present results showing a $^{14}CO_2$- based deconvolution of atmospheric CO_2 measurements into fossil fuel and (by residual,) biological components.

Used in a different way, $^{14}CO_2$ measurements can be used together with inventories of fossil fuel emissions -- the best known component flux in the carbon cycle. Knowing an emissions source and the atmospheric distribution of a tracer for that source allows us to test our knowledge of atmospheric transport. As we make more and more measurements of $^{14}CO_2$ over the United States and elsewhere, these will become powerful constraints for atmospheric transport models. Eventually, we will be able to test not just model transport accuracy but our entire atmospheric top-down source estimation techniques (data assimilations and inversions) by attempting to directly estimate fossil fuel emissions from atmospheric $^{14}CO_2$ data. Along these lines, we present comparisons of simulated and observed $^{14}CO_2$ in a transect across Siberia showing its sensitivity to modeled transport. In the context of the NACP, $^{14}CO_2$ will prove to be a valuable tool both for observational determination of anthropogenic emissions and as a way to evaluate top-down calculations of regional and continental-scale carbon fluxes.

A.12: Estimating local, regional and continental fluxes from the NOAA/ESRL aircraft networ

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Using a combination of vertical profiles made at 19 aircraft sites over the last 10 years and recent inversion results which assimilates the NOAA boundary layer flask network we explore the feasibility of estimating local, regional and continental fluxes from the NOAA/ESRL Global Monitoring Division (GMD) Aircraft Network. Three approaches for estimating fluxes are explored using aircraft profiles: 1) local eddy covariance using deviation in horizontal velocity and CO_2 from the free tropospheric mean to estimate outgoing fluxes at the "downwind" edge of the continental boundaries; 2) inversion techniques which utilizes a semi-lagrangian dispersion model to estimate fluxes from source regions of individual aircraft measurements; 3) a mass balance approach which calculates net surface fluxes by combining a geostatistical interpolation of vertical profiles with climatological winds. The mass balance approach estimates net surface fluxes as the monthly change in the CO_2 inventory minus the net monthly vertical and horizontal transport of CO_2 at the continental boundaries. Daily fields from the inversion results will be used to test how much information is lost with each flux estimating technique using vertical profiles made at bi-monthly time intervals.

A.13: High Resolution Observations of CO2 over Mexico City and the Eastern Pacific during the INTEX-B/MILAGRO Campaign

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The Intercontinental Chemical Transport Experiment-North America (INTEX-NA) was an international field campaign envisioned to investigate the transport and transformation of gases and aerosols on transcontinental/intercontinental scales and assess their impact on air quality and climate. Phase B of the mission series was conducted aboard the NASA/UND DC-8 aircraft during a 10-week period from March 1 to May 15, 2006 with flights initially over the Mexico City Megaplex and Gulf to examine source characteristics of Mexico City and the chemical evolution of its outflow (MILAGRO), later addressing the transport of pollution from Asia to North America during springtime meteorological conditions (INTEX-B). In this presentation, we provide an initial look at preliminary in situ CO2 data collected during large-scale surveys over these regions. We also examine CO and CH4 data acquired using other fast-response instrumentation installed on the DC-8, and we evaluate ensemble characteristics in terms of temporal correlations and species concentration enhancement ratios. Where appropriate, we compare these data to data gathered during previous airborne campaigns.

A.14: Observations of CO2 column abundance at Park Falls Wisconsin

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We present a 2 1/2 year time series of the CO2 total column obtained by high-resolution, direct solar absorption Fourier Transform Spectrometry over Park Falls, Wisconsin. We simultaneously retrieve multiple gases that absorb in the near-infrared, including CH4, CO, H2O, O2, N2O and HF. We use the column measurements to study CO2 variability on multiple time scales. Here, we examine correlations among the retrieved gases to infer the effect of transport on CO2 variability on diurnal and synoptic time scales. We also examine correlations between retrieved columns and dynamical variables calculated from NCEP reanalysis data to quantify latitudinal concentration gradients.

Terrestrial and Riverine Measurements and Inventories, including Flux Measurements

B.1: Ten years of eddy covariance over no-till maize/soybean fields in Illinois.

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Mitigating or slowing an increase in atmospheric carbon dioxide concentrations ([CO2]) has been the focus of international efforts, most apparent with the development of the Kyoto Protocol. Sequestration of carbon in agricultural soils is being advocated as a method to assist in meeting the demands of an international carbon credit system. Conversion

of conventionally tilled agricultural lands to no till is widely accepted as having a large-scale sequestration potential. In this study, carbon flux measurements over a no-till corn/soybean agricultural ecosystem over ten years were coupled with estimates of carbon release associated with agricultural practices to assess the net biome productivity (NBP) of this no-till ecosystem. Estimates of NBP were also calculated for conventionally tilled corn/soybean ecosystem assuming net ecosystem exchange is carbon neutral. The results show that, over a ten-year period, slight carbon sequestration associated with a no tilled field occurs, although the results demonstrate only slight carbon sequestration potential. The inherent errors associated with eddy covariance measurements also must be considered when interpreting these results.

B.2: Organic C dynamics in a pine forest soil with elevated CO_2 and N fertilization

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We assessed soil organic matter (SOM) dynamics via incubations and soil aggregate size and chemical fractions in soils supporting an aggrading pine forest exposed to elevated CO_2 and N fertilization (Duke Forest FACTS site). We exploited the depleted C isotopic signature of the supplemental CO_2 to quantify the fraction of SOM resulting from the additional C after 9 years of fumigation. In laboratory incubations, we assessed microbial respiration to characterize the effect of elevated CO_2 and N fertilization. There was no significant effect of elevated CO_2 on organic C stocks, either in bulk soil or aggregate size or chemical fractions, but the largest size fractions in elevated CO_2 soils had C:N ratios 33% higher than control soils. In elevated CO_2 plots, bulk soil organic C accumulated at a mean rate of 352.7 ± 44.8 µg C g_{soil}^{-1} y^{-1} during approximately 9 years of fumigation, a rate similar to that calculated from Schlesinger and Lichter (2001) after three years of fumigation. Rates of C incorporation into SOM were greatest in the largest size fraction (155.8 ± 23.2 µg C g_{soil}^{-1} y^{-1}) and least in the smallest size fraction (53.9 ± 7.4 µg C g_{soil}^{-1} y^{-1}), typically associated with older, recalcitrant SOM. Incubation data indicate that elevated CO_2 can increase, and fertilization can decrease, microbial respiration of labile organic matter. As more recalcitrant material was accessed, fertilization of elevated CO_2 soils resulted in a 28% decline in respiration, potentially due to an increase in microbial growth efficiency. $\delta^{13}C$ of respired CO_2 in these incubations indicates that fertilization also results in an increase in microbial respiration of ^{13}C-enriched organic components. These data suggest that lower quality organic material with elevated CO_2 can promote greater microbial respiration, while inorganic N availability may mitigate this effect by increasing microbial growth efficiencies.

B.3: Mapping Carbon Pools in the Southwestern US

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Active technologies (radar and lidar) are proving promising for remotely inventorying aboveground biomass although these methods are not yet able to acquire data at regular intervals over large areas. An alternative and complementary approach is the use of multi-angle imaging; here, data from the NASA Multi-angle Imaging Spectro-Radiometer (MISR) on the Earth Observing System Terra satellite were used to estimate the fractional cover and mean canopy height of woody plant canopies; and to map aboveground biomass for parts of Arizona and New Mexico (>200,000 km^2). Red band bidirectional reflectance estimates in nine views mapped to a 250 m grid were used to adjust the Simple Geometric-optical Model (SGM). The soil/understory background signal was decoupled a priori by exploiting relationships with the nadir camera blue, green, and near-infrared reflectance data and the kernel weights of a bidirectional reflectance distribution function (BRDF) model. The SGM was adjusted using the Praxis optimization algorithm. Some areas with shrub cover were predicted to have no woody plant cover, reflecting the difficulty of estimating canopy parameters in low cover environments. Retrieved distributions for forested areas showed good matches with data extracted from US Forest Service maps, with R^2 values of 0.76, 0.58 and 0.53 after filtering for high root mean square error and cloud/cloud-shadow contamination. This is the first attempt to use data from MISR to produce maps of crown cover, canopy height, and aboveground biomass over a large area.

B.4: Estimating Carbon Stocks at the Field-Management Scale

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The objective of this study was to compare alternative approaches for estimating the stocks of soil organic carbon of agriculturally managed fields. We studied two fields (~15 and ~17 ha) in Iowa where soils were developed in Wisconsinan till and loess, respectively. Soils occurred on characteristic landscape positions in quintessential drainage sequences, ranging from well to poorly drained. The fields were sampled in grid patterns at 125 or 143 sampling locations to a depth of 30 cm. Organic carbon content and bulk density were determined for each of three depth increments. The stocks of organic carbon were estimated in three ways: (1) by using a county-specific, expert database to predict soil characteristics, (2) by using classical statistical analyses, in which (a) the data from all sampling points were lumped or (b) in which the data from each mapping unit were stratified and then compared with those from other mapping units, and (3) by using geostatistical analysis, in which data for the entire field were analyzed by semivariograms and kriged maps of the organic carbon distribution. Each approach resulted in a different estimate of the total organic carbon stock of the field. Each approach also yielded a different

estimate of the uncertainty in the carbon stock value. For both fields, the expert database approach gave the largest estimate of carbon stocks, while block kriging gave the lowest estimate. The uncertainty associated with each estimate ranged from <1 to 15% of the estimated stock.

B.5: Modeling variability in biomass consumption for estimating fire emissions

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The study presented focuses on quantification of the variability in fuel consumption for the purpose of estimating carbon emissions during biomass burning. Landsat multi-spectral images are used to determine how much of the landscape is affected by fires of low, moderate, or severe consumption level within 13 forested ecoregions. Field-based measurements of fuel consumption are used to associate the remote sensing-based map of consumption level to the amount of fuel consumed (kg/m2). Fuel consumption in forested ecoregions of western and northern North America where forest fires are prevalent is the region of interest. In this presentation, the approach for mapping and measuring fuel consumption using a combination of remote sensing-based land classification and field measurements is described. Because data available for the boreal and temperate study regions are not the same, different approaches are used in Alaska, Canada, and the western lower-48 study regions. Preliminary results of mapping fuel consumption in Alaska shows a small percentage of the land burns in severe fires, but since this represents a substantial amount of the total carbon emissions, increases in severe fire will result in more extreme emissions events. Results of a model-based assessment of consumption in western lower-48 forested regions provides a quantitative review of the impact of fire on carbon emissions not previously available. Analysis of data provided by the Canadian Forest Service shows high levels of variability in fuel consumption in boreal North America and an uncertainty not yet quantified related to burning of boreal peatlands.

B.6: Validation and Inter-comparison of Global Leaf Area Index products

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Leaf Area Index (LAI) is a key variable to describe the exchange of energy and mass between the canopy and the atmosphere. There are several global LAI datasets currently available, including those from MODIS, CYCLOPES, ECOCLIMAP, CCRS and GLOBCARBON. Understanding both the uncertainty in a given LAI product, and the differences between LAI products, are critical for their proper use. Direct validation is used to establish the absolute accuracy of a given product, while products inter-comparisons help define how multiple products can be used in combination. We have undertaken a validation and inter-comparison of several global LAI remote sensing products in concert with the CEOS Land Product Validation subgroup, which provides an international infrastructure to share data, methods, and results relevant to global product validation.
First, we present results of the first step of this global inter-comparison, using the five LAI products described above, at 10 km spatial resolution and at monthly time steps. The LAI uncertainty is assessed in a systematic and statistically robust way using the BELMANIP benchmark network. This network provides a representative sampling of global surface types. Direct validation of the LAI products is being conducted at BELMANIP sites for which high spatial resolution LAI maps (representing ground truth) have been generated. The spatial and temporal consistency between products is investigated for 2001, 2002 and 2003 over a wide range of surface types. Results are discussed relative to the characteristics of each product.
Secondly, we present early results of testing the sensitivity of land surface models to the type of LAI product used in the model. This analysis is performed over selected FLUXNET sites for which ground measurements of LAI and energy fluxes are available. The land surface model is first calibrated using ground measured LAI. The sensitivity of the model to the different LAI products used is then assessed by comparing the simulated and measured fluxes.
The work presented here demonstrates how both direct validation and product inter-comparison are required for the proper use and understanding of the multiple products currently available as well as the integration of past and future products into a consistent long-term, multi-sensor time series.

B.7: Determinants of Forest Soil Carbon Dynamics in Complex, Mountainous Terrain

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Mountain forests occupy approximately 28% of the Earth's closed forest area. Quantification of soil C stocks in mountainous regions has been identified as a knowledge gap in the North American Carbon Program. In order to predict future forest soil C stocks, we must understand how different environmental factors (temperature, N availability, litter chemistry) affect input and output processes that control amounts of forest soil organic matter (SOM). The goal of this research is to further the understanding of forest soil C and N dynamics in a changing climate, particularly the dynamics of labile SOM in complex, mountainous terrain. In the Great Smoky Mountains National Park, soil C stocks and the

predicted turnover time of soil C increase with altitude, primarily due to declining decomposition rates. A principal component analysis, based on 5 variables related to N availability, also indicates that N availability increases with elevation. Soil C storage and turnover time increase from warmer, drier, less N-rich forests to colder, wetter, more N-rich forests. Furthermore, there are patterns in the vertical distribution of soil carbon-13 abundance that are related to soil C turnover times. Modeling of soil C dynamics indicates regional warming in the southeastern US could produce substantial losses of SOM from both low- and high-elevation forests. However, soil transplant experiments indicate the potential response of forest soil C to regional warming depends on the quality of SOM and that sites with low soil C-to-N ratios are more prone to soil C loss in a warming climate.

B.8: Ecosystem-scale parameters of CO2 exchange and productivity of grasslands and agricultural crops of North America: Comparative analysis and synthesis of flux-tower measurements

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The AmeriGrassFlux data set is based on long-term measurements of the net CO2 exchange (Fc) at 32 North American grassland and crop ecosystems characterizing 68 measurement-years from the AgriFlux and AmeriFlux networks as well as on data provided by individual research teams representing the area from Alberta to Texas and from California to North Carolina. Original Fc data at the 20 or 30-min. time step were partitioned into gross photosynthetic assimilation (Pg) and total ecosystem respiration (Re) components using light-temperature-response functions method (Gilmanov et al., 2003; Stoy et al., 2006) resulting in quantitative estimation of the principal ecosystem-scale characteristics of CO2 exchange and bio-productivity, including apparent quantum yield ALPHA , plateau of gross photosynthesis Amax, daytime ecosystem respiration rate, Rd, daily gross ecological light-use efficiency EPS, as well as calculation of annual totals of gross primary production, total ecosystem respiration, and net CO2 exchange. Functional relationships of CO2 exchange components (Pg, Re, Fc) to meteorological (PAR, temperature, precipitation, humidity), vegetation (LAI, biomass, phenology), soil factors (temperature, moisture), and to remotely sensed factors (NDVI, NDDI, etc.) at various time scales provide an empirical basis for modeling and scaling-up of tower grass/crop CO2 fluxes to landscape and regional levels.

B.9: Remote Estimation of Gross Primary Production of Rainfed and Irrigated Crops

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Accurate estimation of spatially distributed CO2 fluxes is of great importance for regional and global studies of carbon balance. We applied a recently developed technique for remote estimation of crop chlorophyll content to assess gross primary production (GPP) of rainfed and irrigated crops (maize and soybean) at the AmeriFlux site at Mead, NE. The technique is based on reflectance in two spectral channels: the near-infrared and either the green or the red-edge. Results from this technique were compared against the GPP values, calculated from the tower measurements of CO2 fluxes. The technique provided accurate estimations of mid-day GPP in both crops under rainfed and irrigated conditions with root mean square error of GPP estimation of less than 0.3 mg CO2/m2s in maize (GPP ranged from 0 to 3.1 mg CO2/m2s) and less than 0.2 mg CO2/m2s in soybean (GPP ranged from 0 to 1.8 mg CO2/m2s). Validation using an independent dataset for irrigated and rainfed maize showed robustness of the technique; RMSE of GPP prediction was less than 0.27 mg CO2/m2s. We also tested the applicability of the technique using aircraft-based imaging spectrometer AISA and TM Landsat imagery. Both tests showed that the approach allowed accurate estimation of GPP (with RMSE of less than 0.25 mgC/m2/s).
Given the substantial improvement in the accuracy of estimating gross primary production by the algorithms developed and tested in this study, as compared to the currently used methods, it is worthwhile to fully explore the efficacy of these techniques over different crops, at different sites, and through remote as opposed to proximal spectral sensors. Further validation of this technique over other crops and vegetation types is required using the green and NIR bands of satellite-based systems such as MODIS, Landsat TM and ETM, and Hyperion (onboard EO-1 satellite) as well as the red-edge and NIR bands of satellite systems such as MERIS and Hyperion. With further validation (using data from already established FluxNet and SpecNet sites), this technique may be found useful in a variety of terrestrial ecosystems. The end result may be an inexpensive yet accurate tool for estimating net carbon exchange.

B.10: Forest age, topography and dominant tree species affect carbon exchange of central New England forests

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Since 2000, we have measured carbon exchange at a cluster of three flux towers in north-central Massachusetts, to assess influences of stand age, species composition, and topography/drainage on carbon budgets in the northeastern U.S. A deciduous oak-dominated forest about 45 years old on a well-drained hill slope had maximum hourly C uptake in summer of 20-25 $\mu mol\ m^{-2}\ s^{-1}$, versus 25-30 $\mu mol\ m^{-2}\ s^{-1}$ in a generally similar forest 65-100 years old at a less-well drained long-term study site. However ecosystem respiration was also less for the younger forest, resulting in only small differences in annual C storage between the two forests; each stored 2.3-2.5 and 3.9-4.3 Mg C/ha/yr in 2003 and 2004 respectively. Relatively young forest floor and litter layers, developed since a fire in 1957, and occasionally low soil moisture may limit ecosystem respiration in the

younger, drier forest. C exchange for the older deciduous forest varied between SW and NW portions of the tower footprint, apparently due to poor soil drainage (accentuated by beaver activity) and the presence of coniferous trees to the NW. Gap-filling models indicated that in 2003 and 2004 the drier SW area of older deciduous forest had highest C storage of any of the predominantly deciduous forests sampled, followed by the well-drained younger forest. The poorly-drained area of older deciduous forest with some conifers had the lowest C storage. Coniferous eastern hemlock forest had maximum hourly C uptake around 15 µmol m^{-2} s^{-1}, lower than any area of primarily deciduous forest. Hemlock forest stored much less carbon in summer, but compensated for this through autumn and spring C storage and minimal C loss in winter. Fall-to-spring photosynthesis allowed the hemlock forest to store nearly the same amount of carbon as the younger deciduous forest from July 2004 through June 2005. As climate warms, fall-to-spring photosynthesis could increase annual C storage in coniferous forests of the northeastern United States, if ecosystem respiration in summer does not increase dramatically.

B.11: The Curtis Ranch Land Use Change Experiment: Measuring land use change impacts on carbon dynamics in the western Great Plains (Briggsdale, Colorado)

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With funding from the National Institute for Climate Change Research (NICCR) we are investigating how land use change in the western Great Plains impacts ecosystems function and interaction with the regional atmosphere. We are measuring fluxes of carbon dioxide and water vapor between the land surface and atmosphere as a way to understand how grazing and dry-land agriculture change the productivity and water balance of semi-natural grasslands in the shortgrass steppe region of eastern Colorado. We chose to work in Conservation Reserve Program (CRP) land because of the importance of this USDA program in the Great Plains region, and to understand how ecosystem processes change when CRP is returned to grazing or to dry-land agriculture. Moderate grazing by cattle has relatively subtle effects on both carbon and water dynamics in these grasslands in the short term, but differences between grazed and ungrazed systems may become more apparent through time. Conversion of grassland to a wheat-millet rotation resulted in a large loss of carbon to the atmosphere during conversion (~135 g m-2 Carbon) that is only partially offset during subsequent crop growth. If all the CRP land in Colorado (~800,000 Ha) were transformed back to dry-land agriculture the resulting loss in perennial grass biomass could release as much as 1.1 Tg Carbon. In the next phase we will begin restoration of the crop site during which the site will be re-sown to a grass and forb mixture typical of the shortgrass steppe. We will monitor the recovery of the site with anticipated carbon sink over several years, matching in magnitude but not speed the rapid loss of carbon when the site was ploughed. We are developing new physiological modules for the DayCent biogeochemical model to simulate hourly fluxes of carbon and water, to provide coupled growth, biochemical and biophysical models. New very accurate measurements of atmospheric CO2 concentration have been installed to provide data for regional boundary layer inversions to verify the regional model estimates. The trio of flux towers that form the Curtis Ranch Land Use Change Experiment represent some of the most important land uses of the western Great Plains region. These, coupled with modeling and inversion of atmospheric [CO2] measurements, are providing vital information on short-term (hourly to seasonal) and long-term (seasonal-multi-annual) carbon dynamics of the Central Great Plains region.

B.12: Characterizing Organic Carbon Flux from Litter Sources to Mineral-Soil Sinks Enriched Background Isotope Study (EBIS) (1) Summary Results for Upland Oak Forests of Tennessee and (2) Plans for a Distributed EBIS-AmeriFlux Study

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This research provides data on C flux from litter sources to mineral soil sinks for United States eastern hardwood forests necessary for testing process hypotheses and judging efficacy of soil C cycling models. EBIS utilizes releases of radiocarbon resulting in a whole-ecosystem isotopic label near Oak Ridge, Tennessee to study issues associated with terrestrial soil carbon cycles. The EBIS observations support conclusions that intra- and inter-annual soil carbon cycling in hardwood forest soils should be characterized as a two-compartment system where surface leaf-litter and belowground root turnover represents the primary carbon sources for organic-layer and mineral-soil carbon cycles, respectively. After 3-years of litter manipulation and 4 years of tracking, 14C-signatures of bulk organic horizons indicate the arrival of enriched litter into the humus (Oe/Oa) layer with a turnover time of ~9 years. Fractionation of soil C by size/aggregate and density-based methods suggest that labile mineral-soil carbon may also be changing proportionate to their respective leaf or root litter inputs. EBIS experimental findings are being used to parameterize and refine existing carbon dynamics models (Daycent, RothC) and to build new models for the characterization of key process-level features of the soil C cycle.
New experiments are planned to (1) achieve completion of EBIS observations in Oak Ridge, (2) collect new 14C-enriched materials for experimental applications, and (3) apply those materials to multiple AmeriFlux sites over a range of climatic and biological conditions. The experimental data generated by EBIS will contribute to a detailed database for evaluating the next generation of terrestrial carbon models and resolve uncertainties about C fates within AmeriFlux study site soils. The research provides data for addressing DOE's goal of understanding mechanisms controlling C flux, and for the improvement of models to be applied to policy discussions regarding the safe levels of greenhouse gases for the earth's system.

B.13: Using model analyses and surface-atmosphere exchange measurements from the Howland AmeriFlux Site in Maine, USA, to improve understanding of forest ecosystem C cycling

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The Howland AmeriFlux site is located in central Maine, USA, on commercial timberland, the most common land-use type in the state, with stands dominated by red spruce, eastern hemlock, and other conifers. Ecosystem-atmosphere CO2, heat, and water vapor exchange, as well as a variety of environmental and ecological measurements have been carried out at Howland since 1996. Measurements are underway in four stands; 1) undisturbed and mature (~140 year-old); 2) mature but with supplemental N fertilization; 3) recent (2001) commercial shelterwood harvest; 4) 20-year-old regrowth from commercial harvest. The site is about 20 km NW of the Argyle tall-tower.
The work at Howland is focused on understanding how climatic variation influences forest carbon cycling and has several components. These include longterm (>10 year) flux measurements, 14C-based estimates of soil C pool residence times, and the application of inverse analysis (using maximum likelihood and Bayesian approaches) and data-model fusion techniques (Unscented Kalman filter) to bring disparate data together to constrain models of C exchange.

B.14: Nature and Dynamics of Carbon Accrued in a Forest Soil during Five Years of Atmospheric CO_2 Enrichment

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Plant responses to atmospheric CO_2 enrichment, particularly above- vs. belowground allocation of net primary production (NPP), will affect soil organic matter dynamics and stocks. Even when significant changes in soil C are evident, predictions of the potential for long-term stabilization will require studies of C allocation and dynamics in functionally meaningful soil organic matter pools. At the free-air CO_2 enrichment (FACE) experiment on a sweetgum plantation in Oak Ridge, Tennessee, we are using (1) repeated sampling over time, (2) the isotopic tracer provided by the depleted ^{13}C signature of the CO_2 fumigation source, and (3) physicochemical fractionation procedures to determine the fate and dynamics of FACE-derived C inputs to soil. After 5 years of CO_2 enrichment, soil C accumulated at a linear rate in both unprotected and aggregate-protected pools, suggesting that additional C inputs were being processed and cycled in much the same manner as under ambient conditions, without saturation of physical protection mechanisms. New FACE-derived C was found in all fractions, but conservation of existing organic matter appears to account for some of the C accrued in mineral-associated fractions. Analysis of the lignin biopolymer composition and oxidation state of organic matter in isolated soil fractions indicates that C accumulated under elevated CO_2 is mostly derived from roots and is less degraded than C in comparable pretreatment soil fractions. The dynamic changes in this system will contribute to improved understanding and quantitation of the processes involved in soil C turnover and stabilization required by soil organic matter simulation models.

B.15: Incorporation of Radiocarbon from Forest Litter and Roots into Microaggregate-Protected and Unprotected Soil Carbon Pools

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A large release of $^{14}CO_2$ from an industrial source occurred near Oak Ridge, TN in summer 1999. This release resulted in a whole-ecosystem pulse label of ^{14}C in the local forest. A gradient of labeling occurred; sites nearest the source experienced a pulse in excess of that produced by atmospheric weapons testing. For the Enriched Background Isotope Study (EBIS), replicated plots were established in fall 2000 at four sites consisting of two soil types (an Ultisol and an Inceptisol) and two levels of ^{14}C exposure (enriched and near-background). Forest litter was manipulated on these plots through multi-year reciprocal transplants of enriched vs. near-background litter. The differently labeled root and surface litter sources were used to track the source and dynamics of physically and chemically isolated soil organic matter pools. By incorporating elements of physical location (aggregate protection), level of degradation (particle size), and chemical lability (hydrolysis), our soil fractionation separated C pools that differed, on average, in quality and dynamics. Microaggregate protection slowed the dynamics of both particulate organic matter C and mineral-associated C. Although acid-resistant fractions contained far less ^{14}C, increasing ^{14}C signatures over time demonstrated the presence of a highly dynamic component in acid-resistant mineral-associated pools. Dilution of root source ^{14}C and enrichment with leaf litter ^{14}C indicated that both sources contributed C inputs to soils in this upland oak forest. Future modeling efforts will use these data to quantify the relative contributions of these sources to soil organic C and to better understand the mechanisms controlling C fluxes in upland deciduous forests.

B.16: Modeling the Spatial Distribution of Soil Organic Matter: Examples from a Northern Hardwood Forest and a Tropical Forest

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Predicting the spatial distribution of soil organic matter (SOM) has been a challenge for researchers and a major need of resource managers. This study compares SOM modeling techniques used to predict SOM in the Green Mountains of Vermont and in the Luquillo Mountains in Puerto Rico. Each area has datasets that can be used to derive relationships between environmental variables and organic matter concentration and content. The Green Mountain dataset was sampled with the quantitative pit method, which directly measures bulk density and is therefore an accurate measurement of the SOM. This dataset is also interesting because the sampled sites were confined to northern hardwood stands over acid-till soils, allowing us to investigate variation of the soil under the same vegetation, climate and parent material. The Bisley dataset was sampled at high resolution (every 40 meters) and represents a highly variable dissected tropical landscape. In both examples, the relationships derived are meant to reflect the five soil forming factors and aid in modeling spatial variation. Techniques for modeling include the use of Multiple Regression, Multivariate Regression Trees, GIS analysis, and biogeochemical models (e.g. "Century Model"). The strengths and weaknesses of each approach are compared.

B.17: Carbon Dioxide and Methane Fluxes from Northern Forest Soils

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In developing landscape-level carbon budgets, we measured fluxes of carbon dioxide and methane from soils of forests and wetlands in the Marcell Experimental Forest (MEF) and the Chequamegon National Forest (CNF) during the 2005 growing season. At MEF, carbon dioxide efflux from peatland cover types (6.1 Mg ha-1) was lower than that from forested and non-forested upland cover types (7.9 and 10.1 Mg ha-1, respectively). MEF uplands were a slight sink for methane (-0.005 kg C ha-1 d-1), and peatlands were a substantial source (0.31 kg C ha-1 d-1). As peatlands account for approximately 20% of the cover types at MEF, this site acted as a net source of methane during the measurement period. At the CNF, we sampled 7 different field sites representative of vegetation cover classes and forest management regimes in the region. Carbon dioxide efflux was lowest at an open bog site (2.9 Mg C ha-1) and highest in a 5 year clearcut (7.8 Mg C ha-1), with the flux from other wetland types, a mature forest, and a young clearcut ranging from 5.4-6.75 Mg C ha-1). Net methane flux also varied with site, with the mature hardwood site, the older clearcut, and the coniferous wetland acting as sinks for (-1.2, -1.3, and - 0.7 kg C ha-1 respectively), and the younger clearcut, the alder swamp, the bog, and the sedge fen acting as sources (3.7, 0.9, 2.7, and 19.8 kg C ha-1 respectively). Site differences appear to be directly related to differences in temperature, moisture and vegetation.

B.18: Complex Mechanisms Dampen Terrestrial Carbon-Cycle Feedback to Climate Warming: Results from an Experiemntal Warming Study in Great Plains

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Global climate modeling has demonstrated that climate warming would stimulate respiratory CO2 release from the terrestrial ecosystems to the atmosphere, which in turn leads to more warming in the climate system. This positive feedback between the climate change and the terrestrial carbon cycle potentially leads to a dangerous threat to ecosystem functioning and service. Some of the key processes underlying this feedback loop, however, have not been carefully examined by experimental studies. We have conducted two warming experiments in a Southern Great Plains prairie to examine ecosystem responses to climate warming. We used infrared heaters to elevate soil temperature by approximately 2.0 and 4.0 oC, respectively, during the experimental period. Our results indicate that plant biomass growth increased by approximately 20\% in the warmed plots in comparison to that in the control plots. The increased plant productivity resulted from extended length of growing seasons since warming advanced phenology of early-flowering species and delayed phenology of late-flowering species, leading to an extension of the growing season. Warming also considerably increased C4 plant biomass and caused slight decreases in growth of C3 plants. Increased C4 biomass and litter production resulted in decreases in quality and decomposition of bulk litter at the ecosystem scale, leading to an increase in litter mass at the soil surface. Soil respiration did not significantly increase in the first two years but increased by 8-10\% in the last several years, largely due to increased root respiration and litter pool sizes. We did not observe much change in soil C content under warming, indicating that increased plant biomass counterbalanced the increased carbon loss via respiration. Overall, our data from the Great Plains prairie do not support the notion that warming stimulation of soil respiration is the major feedback process to climate change.

B.19: Carbon Cycling in Mature and Harvested Black Spruce Forests in Eastern Canada

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Ecosystem-level carbon (C) fluxes were measured from June 2003 to December 2005 over a mature boreal black spruce forest and from January 2003 to December 2005 over a black spruce cutover site located near Chibougamau, Québec. An operational scarification treatment was applied at the end of October 2003 at the harvested site while the mature stand structure was not disturbed during the study period.
In 2004 and 2005, the mature stand was C neutral (Net Ecosystem Productivity (NEP) = 0 - 6 g C m-2 y-1) while the harvested site was a strong C source of 167 to 119 g C m-2 y-1 from 2003 to 2005. Sensitivity of total annual Gross Ecosystem Productivity (GEP) and ecosystem respiration (R) to variable environmental conditions was high at both sites. The variability in the annual C budget of the sites was mostly determined by the timing of the beginning of the growing season at the mature site and by mid-summer temperatures at the cutover site
Light, air temperature and vapor pressure deficit (VPD) affected GEP at both sites. High air temperature and VPD had a stronger limiting effect on GEP at the mature site.

B.20: Soil Organic Carbon at Depth in Cultivated Fields is Greater than in Native Lands on Wet Mollisols of the U.S. Midwest Region

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We compared the distribution of soil organic carbon (SOC) at depth in cultivated versus native lands of the U.S. Midwest by using a paired rowcrop-prairie remnant field design across Iowa, Illinois, and Wisconsin. The sampled soils represented typical poorly drained Aquolls that occur within the glaciated Corn Belt region. Each study site consisted of a historically known tallgrass prairie remnant and a nearby long-term-cultivated field under corn/soybean rotation, in corn at the time of the study, on the same soil series. The soils were sampled to 1 m depth and sectioned at small intervals. Roots and organic debris were removed from each section and bulk density, texture, delta^{13}C and SOC were quantified for each section of each soil. Cultivated soils had lower C concentrations in surface soils that amounted to a 12 to 32% reduction in SOC to a depth of about 25 cm. However, the cumulative SOC for the entire profile was significantly greater in cultivated soils than in remnant soils. This increase varied from 8 to 30\% depending on soil series, potentially accounting for as much as 4 kg C m^{-2}. Carbon gains at depth appeared to result from the mixing of surface and subsurface soil during tillage practices, which distributed soil with greater C concentrations deeper in the soil profile. These results suggest that the depletion of SOC in cultivated lands located on poorly drained Mollisols in the U.S. Corn Belt might have been overestimated. Thus, assumptions that the depletion of SOC at shallow depths mostly represents past losses of C to the atmosphere or erosion may be incorrect for these soils.

B.21: Quantifying the carbon budget of developed land use in North America

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The rate at which wildlands and croplands are being developed for human settlement in the United States currently exceeds population growth by a factor of two to four. Developed land areas represent major sources of CO_2 and other radiatively-important trace gases due to the concentration of human activities that consume fossil fuels. However, they are also ecosystems with significant vegetation covers that take up CO_2 and soils that release CO_2. Direct measurements are needed to quantify the land-based sources and sinks of CO_2 in developed areas, especially residential developed land, which accounts for most of the land-use change. We are quantifying the components of CO_2 exchange in a first-ring suburb of Minneapolis-St. Paul, Minnesota, using tracer measurements, traffic and energy-use monitoring, and time-series analyses. Second, we are determining the controls on biotic fluxes from measurements of a suite of biophysical properties measured for each surface or plant functional type (PFT; deciduous and evergreen trees, turfgrass, bare soil, and impervious or constructed). And third, we are developing algorithms for each PFT to estimate component CO_2 fluxes from remotely-sensed data. Biophysical properties and PFTs are mapped using multi-resolution satellite imagery (QuickBird, 2.4-m, and Landsat TM/ETM+, 30-m pixel) and linear mixing models. Currently, a flux time series of >1 year has been produced and initial parameterizations of a production efficiency model (PEM) driven by absorbed photosynthetically-active radiation (APAR) and a soil respiration model driven by temperature (air and land surface temperature) have been developed.

B.22: Determining Ecosystem Light Use Efficiency from MODIS

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An accurate determination of the spatial and temporal distribution of photosynthetic CO2 uptake is required to understanding the dynamics of the global carbon cycle. Stress

factors may result in photosynthetic down-regulation, decreasing ecosystem carbon uptake. Present approaches to determine ecosystem carbon exchange rely on meteorological data as inputs to models that predict the relative photosynthetic function in response to environmental conditions inducing stress (e.g., drought, high/low temperatures). Photosynthetic down-regulation is also related to changes in the apparent spectral reflectance of leaves. This study examines the determination of ecosystem photosynthetic light use efficiency (LUE) from satellite observations, through measurement of vegetation spectral reflectance changes associated with physiologic stress responses. This approach is possible using the Moderate-Resolution Spectroradiometer (MODIS) on Aqua and Terra to provide frequent, narrow-band measurements of high radiometric accuracy. Reflective MODIS ocean bands were used to calculate the Photochemical Reflectance Index (PRI), an index that is sensitive to reflectance changes near 531nm associated with vegetation stress responses exhibited by photosynthetic pigments as well as other reflectance indexes. MODIS PRI values are compared with LUE calculated from half hour values of CO2 flux measured at the overpass time at flux towers at several Fluxnet-Canada network sites. Preliminary results show a good correlation between MODIS PRI and LUE. However, the relationship can be difficult to detect due to differences in viewing geometry of MODIS result in varying fractions of illuminated and shadowed canopy being observed.

B.23: Using model data fusion to estimate Gross Primary Productivity and Ecosystem Respiration from long term measurements of Net Ecosystem Carbon Exchange of a High Elevation Forest at Niwot Ridge, CO.

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High elevation forests make a substantial contribution to the net carbon uptake in the Western US. Measurements of the Net Ecosystem Exchange (NEE) of carbon in these forests are fundamental to carbon accounting in the Mountain West. Predictions of changes in NEE in response to climate and atmospheric change is problematic since NEE is a small difference between two large carbon fluxes; GPP and Re that respond differently to environmental changes. We coupled SIPNET (Simple Photosynthesis EvapoTranspiration), a simplified model of ecosystem function, with a Metropolis simulated annealing algorithm to find both the single best parameter set and an estimate of the posterior distribution of the parameters. Using these optimized parameters the model can accurately match observed fluxes; this allows the decomposition of NEE into its component parts GPP and Re. The model data fusion showed that the seasonal pattern of NEE is controlled by the interplay of these two component fluxes and inter-annual variation in NEE was explained by yearly variation in GPP rather than Re.

B.24: Trends in CO2 Exchange at Harvard Forest

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We have been observing CO_2 fluxes , biomass, and meteorology from a mixed deciduous forest in central Massachusetts. Annual carbon fluxes at this site are quite variable, but significant trends are evident in the long-term record; magnitudes of both photosynthetic uptake (GEE) and ecosystem Respiration (R) were increasing (11.1 + 0.36 y^{-1} and 9.82 + .22 y^{-1} Mg-C $ha^{-1}y^{-1}$ since 1990, respectively). Because GEE is increasing faster than R, the overall magnitude of net ecosystem exchange (NEE) has been increasing (1.28 + 0.15 y^{-1} Mg-C $ha^{-1}y^{-1}$ since 1990). The increasing uptake rate is unexpected for this 75-110 year old forest. There were parallel increases in mid-summer photosynthetic capacity at high light level (21.5 - 31.5 µmole $m^{-2}s^{-1}$), woody biomass (101 - 115 Mg-C ha^{-1} from 1993-2005, mostly due to growth of one species, red oak), total leaf area index (4 - 5.5 from 1998-2005), and a slight increase in coarse woody debris (CWD). The long term trends were interrupted in 1998 by sharp declines in photosynthetic capacity, NEE, and other parameters, with recovery over the next 3 years. Episodic mortality events contribute varying inputs to CWD. Tree-ring analysis of 20 regional cut and uncut red oak populations indicates that tree-level average annual carbon increment is increasing rather than decreasing with stand age. These findings suggest that the increasing uptake rate at the HF may be a more general feature of red oak forests across the region.

B.25: Measurement Network for Soil Organic C Stocks in US Agricultural Lands

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Soil organic C stocks can have a large influence on the net exchange of CO2 between agricultural lands and the atmosphere, particularly over annual to decadal time scales. Moreover, soil organic matter serves many other roles in the ecosystem that are beneficial for crop and forage production, such as improved fertility and moisture retention. Current rates of change in soil organic C are relatively modest at 30 Tg CO2 eq. yr-1 across US agricultural lands, but could potentially increase to rates of 250 to 700 Tg CO2 eq. yr-1. Thus, a measurement-based network is being developed in US agricultural lands, which will be used to monitor soil organic C stocks in combination with remote sensing, land survey data and simulation modeling.

A pilot study for this network has been funded through the North American Carbon Program, and will be used for an initial analysis in the Mid-Continent Region of the US. The network is being developed in conjunction with the USDA National Resources Inventory Program, which conducts a land use survey through repeated sampling at permanent site locations. For the pilot study, approximately 30 NRI sites have been sampled in Mid-Continent Region, using a triangular plot design to minimize within site variance. The first sample has been collected at the corners of the triangle. Repeated sampling will occur every 5-10 years along the sides of the triangle until reaching the next corner over about a 100 year time horizon. Three triangles are being sampled at each NRI site. The soil organic C measurements will serve as evaluation data for the simulation modeling results to improve estimation of carbon sources and sinks in US agricultural lands.

B.26: Controls of Net Ecosystem Exchange at an Old Field, Pine Plantation, & a Hardwood Forest Under Identical Climatic & Edaphic Conditions

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Convective rainfalls are essential for vegetation function in regions where growing season precipitation is dominated by such rains. In the southeast, abandoned agricultural fields, pine plantations and broadleaf deciduous forests use the same amount of water. Yet, the net ecosystem carbon exchange is lowest in the field, highest in the pine during years with ample growing season rainfall, and highest in the broadleaf forest during years with severe droughts. We found that the field vegetation and pine plantations tend to increase sensible heat flux with the intensification of droughts, thereby increasing the likelihood of convective rainfall. In regions dominated by such vegetation covers, this feedback may reduce drought effects on net ecosystem carbon exchange.

B.27: The effects of elevated CO2 on carbon allocation in forests: New results from the Duke Forest FACE Experiment and synthesis of published data

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Leaf area index (L) reflects the growth resources at a site, including water, nutrients and atmospheric [CO2], and the effects of disturbances, such as ice-storms, and can be obtained from remote sensing systems. Under ambient [CO2], sites with more resources and less impact from disturbance events supported a greater canopy leaf area, higher aboveground production, and lower carbon allocation to belowground processes relative to poor or disturbed sites. In moderate to high fertility sites, aboveground biomass production was the dominant sink for the extra photosynthate fixed under elevated [CO2], entirely accounted for by [CO2]-induced increases in leaf area index. In low fertility sites, the extra photosynthate fixed under elevated [CO2] was allocated belowground, where heterotrophic organisms rapidly cycled carbon back to the atmosphere as CO2. The proportion of aboveground biomass production occurring in wood, a moderate-term carbon storage pool, was also related to leaf area index—increasing with leaf area index in broadleaf species in a similar manner under both ambient and elevated [CO2], and decreasing in loblolly pine, but with higher allocation to wood under elevated [CO2].

B.28: Carbon storage and fluxes over a sagebrush burn chronosequence

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Shrub dominated ecosystems have been identified as a potentially important sink for C on a continental scale. Big sagebrush (Artemisia tridentata) ecosystems, covering over 10% of the North American land area, are subjected to management activities that may increase or decrease C storage. Prescribed burning across the Intermountain West removes woody vegetation and increases herbaceous forage to improve conditions for cattle and wildlife, but consequences of burning for carbon and nutrient cycling are poorly understood. We conducted measurements of CO2 fluxes and aboveground and belowground C pools across a ~40-year chronosequence of sagebrush succession following fire. Belowground C storage in root biomass and soil organic matter demonstrated an important legacy from previous vegetation, with near-steady-state conditions found in fine root biomass and SOM. Coarse root biomass increased as shrubs recolonized the burned area. Aboveground biomass increased from 0 to 600 g m-2 while belowground biomass increased from 450 to 700 g m-2 over 40 years. CO2 fluxes demonstrated the importance of soil moisture availability as a key regulator of C cycling. Younger plants of all

functional types showed increasing down-regulation of both light dependent and independent reactions of photosynthesis with decreasing soil moisture. CO2 efflux, measured as night-time net ecosystem exchange and soil respiration, had no relationship with soil temperature, but significant relationships with soil moisture. CO2 fluxes were more sensitive to drought in early successional, herbaceous vegetation than in late successional shrub-dominated vegetation. Drought sensitivity of ecosystem productivity is a consequence of prescribed burning that land managers should consider.

B.29: Gas and Water Vapor Exchanges in Rainfed Corn-Soybean Systems in Iowa

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Corn and soybean production in the Midwestern United States represents one of the most intensive and extensive cropping systems in the world. It is critical to understand the dynamics of CO2 and H2O vapor exchanges above corn and soybean canopies in rainfed environments in order to provide insights into how these cropping systems respond to the combination of management and meteorological conditions. Agricultural production system depends upon C and H2O as two of the primary building blocks yet little is understood about the dynamics of these components over different crops and among growing seasons. The Iowa Ameriflux site encompasses year-around measurements over adjacent corn and soybean fields at a height of 5 m above the canopy. An additional site has been established at 10 m between the two fields to provide a more regional scale estimate of the fluxes across the two cropping systems. Additional within field measurements are made of the soil CO2 exchanges and within canopy CO2 and H2O vapor fluxes. Ancillary data on crop growth, yield, and management practices have been recorded for each growing season and crop. Data have been quality controlled for this site. There are seasonal changes in the magnitude of the fluxes and the resulting NEE for both corn and soybean. This is well known given the differences between C3 and C4 vegetation. A complete C and H2O balance for the typical cropping systems provide a baseline from which comparisons can be made on the expected changes in C storage that would result from changing management practices.

B.30: Uncertainty in tower-based measurements of carbon and energy fluxes: A multi-site analysis

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- Measured flux data, X, represent the true flux, F, plus or minus some random measurement error, ?, plus or minus any systematic errors, ε: X = F + ? + ?. The random measurement error ("flux uncertainty") is distinct from potential systematic errors due to incomplete spectral response or lack of nocturnal mixing (u*). It is necessary to know the characteristics of the flux uncertainty ? for model-data syntheses (i.e., properly conduct maximum-likelihood estimation when assimilating models and data), to make valid statistical comparisons between measured and modeled data, or to estimate confidence intervals on annual flux sums.
- Data from seven sites (five forested sites, one grassland, and one agricultural site) are used to show that the uncertainty in measured fluxes (H, LE, and FCO2) follows a double-exponential, rather than a normal, distribution, and increases as a linear function of the magnitude of the flux.
- Variation in the flux uncertainty follows similar patterns at the different sites. The flux uncertainty decreases with increasing wind speed for FCO2 but not for H or LE.
- These results provide a foundation for incorporating flux data uncertainty information in model-data assimilation problems. Because the random error is non-normal and heteroscedastic (non-constant variance), two of the assumptions underlying least squares optimization are violated. Maximum likelihood estimation techniques, which make use of information about the error distribution, are therefore preferred.

B.31: Organic Carbon Pools in Post-Agricultural and Old-Growth Forest Soils of Western New England

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We are in the process of developing chronosequences of post-agricultural soil C accumulation in western New England. Our initial approach is based on quantitatively sampled forest soils which were formerly used for (a) cultivated crops, (b) hay or pasture and (c) woodlot where the time since abandonment is known from land-use records, old photos or paintings, and recollections of people who worked or lived on or adjacent to the parcels in question. We consider the endpoint of C accumulation to be the current C content of soils of well documented old-growth stands on the more level landscape positions in the region. The patterns and changes in land use in the Hopkins Memorial Forest (HMF) in

Williamstown, MA have been studied for 3 decades, and chronosequences of the three major agricultural land uses have been identified and sampled with time since abandonment ranging from 40-175 years. Old growth stand(s) in the HMF have been sampled for comparison. The soils of the HMF are principally Dystrochrepts or Eutrochrepts derived from acid or slightly calcareous glacial till. If patterns of increased C accumulation with time since abandonment can be validated, we will expand the study to include forest soils of the colder, higher elevations in which the soils are principally Spodosols, and where we can determine precisely time since abandonment and former use. There are major unknowns that may obscure the historical trends in C accumulation, such as the length of time the soil was in agricultural use prior to abandonment, shifts in land use during the period of agricultural use, and differences in edaphic factors that are difficult to control for such as topographic setting and erosion history, soil textural class, drainage class and the species composition of the aggrading forests. Further, the old-growth stands in the region are largely (but not entirely) on steep slopes unsuitable for agriculture, so proper comparisons of soil C in the chronosequences to soils of old-growth sites depends on locating level sites with deep soils within the areas of old-growth.

B.32: Comparison of MODIS and tower-derived albedo values

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Tower-derived albedometer measurements from a number of sites (maintained by Ameriflux, ChEAS, Surfrad, BSRN, LTER etc.) are used to validate the MODIS Albedo Product and establish its accuracy for modeling studies. The MODIS product is produced by using multi-day, cloud-free, atmospherically-corrected, surface reflectances and a bidirectional reflectance distribution function (BRDF) model to ascertain the anisotropy of the surface at a 1km or 500m resolution. The intrinsic directional-hemispherical reflectance (black-sky albedo) and bihemispherical reflectance (white-sky albedo) can be derived from an integration of the surface anisotropy model and then can be coupled with instantaneous atmospheric information to obtain actual (or blue-sky) albedo data such as collected by tower based albedometers. However, the spatial scaling issues encountered in rigorous comparisons of large footprint satellite quantities with tower point measurements can be considerable, as can the temporal considerations. During the summer of 2006, validation efforts were focused on the Park Falls, Wisconsin and Bondville, Illinois tower sites where comparisons of high quality tower data and satellite products were augmented by high resolution imagery and field vegetation characterizations. Additional albedometer data, collected at towers in deciduous forest at the Harvard Forest LTER site and at Boston University's Sargant Camp, will also be presented.

B.33: A Hemispherical Scanning, Below-Canopy Lidar for Rapid and Accurate Retrieval of Forest Vegetation Structure

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We describe a ground-based, upward hemispherical-scanning lidar, the Echidna instrument, to retrieve forest canopy structural information, including tree height, mean tree diameter, basal area, stem count density, foliage profile, leaf area index, and, by allometric calibration, crown diameter, woody biomass, and green biomass. The instrument, developed by CSIRO Australia, scans the canopy with lidar pulses at a wavelength of 1064 nm, digitizing the entire return waveform. Beam width, divergence, sampling rate with distance, and laser power can all be adjusted to meet site and data requirements. We demonstrate the application of provisional algorithms to retrieve many of the structural parameters listed above at two sites near Tumbarumba, southern New South Wales, Australia, containing plantations of Pinus ponderosa and Eucalyptus nitens. Our NASA-supported project will link vegetation structure with lidar waveforms from Echidna , LVIS (Laser Vegetation Imaging Sensor), and GLAS (Geoscience Laser Altimeter System) using a hybrid geometric-optical radiative-transfer (GORT) model, with the goal of remote retrieval and mapping of vegetation structural parameters over large areas.

B.34: The importance of heterogeneity: integrating lidar remote sensing and height-structured ecosystem models to improve estimation of forest carbon stocks and fluxes.

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Lidar remote sensing data have been shown to effectively represent forest structure, constrain estimates of carbon stocks and, when used to initialize a height-structured ecosystem model fluxes, constrain fluxes. Here we use large-footprint lidar data from the NASA Laser Vegetation Imaging Sensor (LVIS) to initialize the height-structured Ecosystem Demography (ED) model to study forest structure and dynamics at Hubbard Brook Experimental Forest (HBEF). HBEF is in the White Mountains of New Hampshire and includes heterogeneity in elevation dependent abiotic factors (i.e. temperature, precipitation, and soil depth), which are important drivers in a well documented decline in biomass and species change with elevation. We produced an estimate of the forest structure and fluxes in 1999 across all elevations at HBEF by first spinning up the model with elevation dependent climate and soil characteristics and then initializing the model using 1999 LVIS canopy height data. We validated the initialized model estimates against extensive field data and demonstrated that above ground carbon stocks, basal area, and species composition were within 1, 5 and 7%, respectively, of the field data at all elevations. Model projections were validated using data from a second LVIS acquisition obtained in 2003, accounting for the effects of both model uncertainty and lidar uncertainty. The additional constraint provided by including elevation dependent abiotic heterogeneity in the model initialization suggests that the forest is closer to a mature state than when initialized without the heterogeneity. We conclude that together lidar data and a height-structured ecosystem model give more information about forest structure and dynamics because together they account for critical fine scale heterogeneity.

B.35: High frequency measurement of soil CO2 efflux at Harvard Forest

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Soil CO2 efflux is an important component of the terrestrial carbon budget. Spatial variation of organic matter and plant cover induce temperature and moisture gradations that obscure direct response of soil respiration to radiative forcing. Separation of spatial patterns from microclimate and substrate availability is vital to predict the response to global change. We measure temporal and spatial patterns of soil CO2 flux across a hydrological gradient from wetland to upland, in mature forest, and an adjoining shelterwood cut site. A transect of 10 automated chambers were installed across a gradient of depth to ground water on the northeast margin of the "Beaver Swamp" north of the EMS tower (+42.5378,-72.1715). The first eight are dark chambers and were installed in April 2003. Two additional clear chambers in the beaver swamp itself in April 2006. Each automated chamber closes for a measurement every three hours. The resulting semi-continuous data provides a high temporal density characterization of soil flux across a depth-to-ground-water gradient.
These automatic chamber measurements will provide a database of upland soil CO2 efflux, wetland net ecosystem exchange, soil and peat temperature, and soil moisture with both high temporal resolution, across multiple cover types and ground water levels. Our measurements are intended to answer two basic questions:

1.) What are the controls on the diurnal and interannual variability of soil CO2 efflux along a wetland to upland gradient?
2.) Are the tower eddy covariance estimates of nighttime CO2 fluxes accurate?

Automated chamber flux systems provide independent, accurate, and simultaneous measurement of nocturnal CO2 efflux, and therefore a means to quantitatively partition the components of the net efflux. By doing so it is also a means to evaluate and constrain the eddy-flux measurements.

B.36: Carbon Dioxide Exchange in Rainfed and Irrigated Agricultural Ecosystems

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In 2001, we established a state-of-the-art, interdisciplinary, field research facility (at the University of Nebraska Agricultural Research and Development Center at Mead, NE: an AmeriFlux "cluster" site) that allows a comprehensive study of carbon (C) exchange in major agroecosystems of the north-central USA. In this poster, we will discuss the annual distributions of net ecosystem production (NEP) during the first four years of no-till farming in three cropping systems: (i) an irrigated continuous maize system, (ii) an irrigated

maize-soybean rotation, and (iii) a rainfed maize-soybean rotation. Gross primary production (GPP) and ecosystem respiration (Re) will be quantified. For example, on an annual basis, the GPP in irrigated maize ranged from 1500 to 1800 g C m-2 (from planting to planting). Of these amounts, about 65 to 75% was emitted as Re, thus the annual NEP ranged from 360 to 570 g C m-2. The annual GPP of soybean was only 45 to 55% of maize GPP with or without irrigation. The annual soybean Re, however, was about 3 to 5% larger than its GPP, which resulted in an annual NEP in soybean of about -10 to -75 g C m-2. Using the eddy covariance flux measurements, we will also present our results on net carbon sequestration over two complete cycles of the 2-year maize-soybean rotation systems and four years of continuous irrigated maize. Also included in our poster will be: a) a comparison of cumulative daily gain of C by the crops (from planting to physiological maturity) determined from the measured eddy covariance CO¬2¬ fluxes and estimated heterotrophic respiration against the measured total above and belowground biomass and b) an analysis of intrinsic fossil-fuel C costs of crop management practices.

B.37: Biometric and Micrometeorological: Integrated Carbon Flux Analysis in a Mid-Latitude Deciduous Forest

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Current estimates of C uptake need to be verified and placed in a larger context of the global C budget in an effort to better predict climate change. In this study, we compare six years (1998-2003) of forest carbon budget estimates obtained by two independent methods: the micrometeorological approach (based on eddy-covariance measurements), and the biometric method (based on carbon stock increment measurements) in a mixed hardwood forest in the Morgan-Monroe State Forest, Indiana, USA. Both methods, when used conjunctively, are keys to understanding carbon cycling in terrestrial ecosystems, particularly when identifying factors driving inter-annual variability in carbon uptake. One goal was to determine the consistency of spatially and temporally integrated estimates of net ecosystem production (NEP) and net carbon (C) sequestration using both methods for a multi-year (1998-2003) period. Biometric estimates of net ecosystem production (NEP) for each of the six years ranged from 267-379 g C m^{-2} y^{-1} and eddy covariance estimates were from 237-374 g C m^{-2} y^{-1}. The cumulative estimates of both methods for the six-year period are within 3% of each other. The ecosystem structure (primarily 60-80-year old secondary succession hardwood forest) and management history of the site (periodic selective cutting) are quite representative of the majority of forests from a wider region. Consequently, these results provide evidence that mid-latitude forests of the northern hemisphere can serve as a large sink in the global C cycle.

B.38: Novel Non-Destructive Soil Carbon Analysis; I - Principles

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In spite of intensive efforts the discrepancy between the models of the “top-down” atmospheric budgets and of the “bottom-up” ecosystem inventories still needs to be reconciled. This together with poorly understood “sink” processes and the need to determine the carbon balance of North America calls for improved and expanded carbon database. One of the main objectives of the Mid-Continent Intensive (MCI) is to provide model validation data using new independent sampling schemes of the carbon cycle components. Inaccessibility to the belowground carbon processes and stocks is a limiting factor in the carbon cycle research. Current method of coring is destructive, labor intensive, expensive, and provides point information. Similarly, eddy-covariance towers are much localized and the results need to be extrapolated to larger regions. A new method for carbon analysis in soil in situ that is non-destructive and can be used in either stationary or scanning modes is presented. It is based on gamma ray spectroscopy induced by inelastic scattering of fast neutrons (INS) that probe a soil volume of approximately 0.3 cubic meter to a depth of 25 to 30 cm (few hundreds kg of soil). When operated in a scanning mode it provides a true average of the scanned area that can be arbitrarily large (acres, hectares).
Once calibrated the INS method offers unique advantages over the existing method that include; 1) capability of true sequential measurements, 2) it views large volumes when used in stationary mode, 3) it provides regional readings when scanned at standard tractor speeds of about 5 miles per hour, 4) it provides concurrent multielemental analysis of C, N, K, and possible P, 5) can be used for validating flux towers estimates of carbon sequestration over large areas, and 6) for regional calibration of satellite images.

B.39: Developing the Flux Fragment Method for Analysis of Data Collected Using an Aircraft-Based Eddy Covariance System

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While flux towers using eddy correlation methods, provide excellent temporal flux data, they are often poor indicators of the spatial variance in fluxes that is common in many landscapes. Aircraft have been successfully used to measure spatial fluxes. However, traditional averaging techniques rely on 3-4km average distances. Therefore, any properties associated with length scales shorter than this distance cannot be assessed using the averaged flux data. If the purpose of an aircraft flux campaign is to obtain sub-regional (10-100km) estimates of flux, then the current methodologies are very appropriate. However, if one is to determine the flux associated with landscape features that are heterogeneously distributed (such as farm fields), then the current methodology becomes problematic. A new methodology of aggregating flux within a single flight transect, not based on position but on landscape features has been developed.
This new methodology has been dubbed the flux fragment method (FFM). It utilizes high resolution land classification data and a cross-wind footprint model to group flux fragments by landscape features, in this case crop type (either maize or soy). Once aggregated, these fluxes represent the spatial flux but separated per crop type. Once this separation has been performed, these fluxes can be coupled with regional land classification data to obtain regional estimates. The fluxes from this method compare very well to single tower estimates (from short towers with field-constrained footprints). Further testing is being performed in several different ecosystems to define the limits of this approach.

B.40: NACP ACCESS: Improving access to MODIS biophysical science products for NACP investigators

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NACP ACCESS is a NASA-funded project supporting the North American Carbon Program (NACP). The purpose of this Advancing Collaborative Connections for Earth-Sun System Science (ACCESS) project is to provide researchers with Moderate Resolution Imaging Spectroradiometer (MODIS) biophysical data products that are custom tailored for use in NACP model studies. The NACP ecological and climate models require high quality continuous biophysical parameters as inputs or validation sources. The MODIS biophysical products provide such data sources and have been used to improve our understanding on the climate and ecosystem changes. However, direct uses of the MODIS biophysical parameters are constrained by retrieval quality and cloud contamination. New temporally smoothed and spatially continuous MODIS biophysical data sets from our processing provide ideal data sources for those applications. We are also addressing a major challenge for researchers, namely, acquiring MODIS data at suitable spatial-temporal resolutions and in formats consistent with data integration into model studies.

B.49: Variations in Global Terrestrial Primary Production and Evapotranspiration Observed by the Moderate Resolution Imaging Spectroradiometer (MODIS), 2000-2005

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The first Earth Observing System (EOS) satellite Terra was launched in December, 1999, and the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard began providing data in February, 2000. We now have a six-year 1-km terrestrial Gross (GPP) and Net (NPP) Primary Production dataset. We present the variations (seasonality and inter-annual variability) of GPP/NPP for North America from the latest Collection (C4.8) for 2000-2005. Validation results show that the C4.8 data have higher accuracy and quality than previous versions. Analyses of the variations in GPP/NPP show that GPP reflects the strong seasonality of photosynthesis in mid- and high-latitudes, the major contributors to global GPP seasonality. Inter-annual variability in MODIS NPP for 2000-2005 reveals the negative effects of major droughts on carbon sequestration at the regional and continental scales.

Evapotranspiration (ET) is an important land surface process linking ecosystem carbon and water cycles. We have modified a Penman-Monteith algorithm to estimate ET (0.5-deg resolution) for North America using MODIS remote sensing data and global meteorological data. Tested at 21 AmeriFlux eddy covariance tower sites, our algorithm shows good agreement with site data. Estimates of seasonal and annual ET (2000-2005) show reasonable spatial patterns, with high ET corresponding to areas with high precipitation and high productivity, although there are differences resulting from differing climatic controls on carbon versus water fluxes. ET increases across most of North America, while decreasing in most of the rest of the world during this time period, affecting agricultural yield and water resources.

Coastal and Oceanic Measurements

C.1: A preliminary synthesis of air-sea CO_2 flux and an exploration of control mechanisms in the US east coast and other western boundary current shelves

Wei-Jun Cai, University of Georgia, wcai@uga.edu (Presenting)

It is increasingly recognized that air-sea CO_2 flux and carbon budget in continental margins represent an important knowledge gap in global carbon cycling research. In the east coast of the North America, until very recently, the US Mid-Atlanta Bight is the only shelf that annual air-sea CO_2 flux was measured (by Takahashi, DeGrandpre et al.). While this shelf acts as a moderate sink of atmospheric CO_2, its overall carbon flux to the open ocean is not known. The central part of the South Atlantic Bight (SAB) was reported as a source of CO_2 to the atmosphere as a result of decomposition of organic matter exported from rivers and the productive salt marshes. Our recent whole shelf seasonal survey, however, defines the entire SAB as a weak CO_2 sink. Large seasonal changes occur mostly in the spring and fall. It appears that temperature is the most important control on surface pCO_2 and that organic carbon production and respiration are closely coupled in the SAB. Preliminary data collected in the Gulf of Mexico (GOM) suggest that air-sea CO_2 flux and carbon recycling are extremely patchy in the North America's largest marginal sea with the freshwater dominated area being a strong CO_2 sink and the rest of GOM most likely being a CO_2 source. Because of its large area and strong signal, the size and direction of the CO_2 flux in the GOM would have a major influence on the overall coastal ocean air-sea CO_2 budget in the North America (see my poster on the 25&26 meeting). In the northern end of the North America east coast, the Gulf of Maine and the Nova Scotia shelf

is most likely a moderate sink of atmospheric CO_2 although reliable data are limited to its southern-end (Vandemark and Salisbury, per. Comm.). Characteristics of these and a few other western boundary current shelves are compared. Temperature, terrestrial input, shelf depth and stratification, existence of spring bloom etc are identified as the most important factors controlling the carbon cycling and the size and direction of air-sea CO_2 flux.

C.2: Air-sea CO_2 flux and carbon budget in the Gulf of Mexico: State of knowledge and research initiatives in North America's largest marginal sea

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The Gulf of Mexico (GOM) is a subtropical marginal sea with 80% of the area being continental margin. The GOM may be divided into four parts: the West Florida Shelf (WFS); Northern GOM; East Mexico shelf; and Yucatan-Campeche shelf. The carbon cycle in the GOM is distinctly different between the river-dominated and non-river-dominated regions. In the former, rivers deliver large amounts of POC, DOC, and sediments to ocean margins, but the fractions of recycled vs preserved carbon are not known. Nutrient-rich river water also supports high levels of primary production in the GOM shelf, particularly, in the Mississippi River plume. Many of the key features of the carbon cycle in these river-dominated regions are centrally dependent on an understanding of the rates of organic carbon degradation in the water column and sediments. In contrast, the other shelves in the GOM have minimal river influence and receive nutrients mostly from subsurface water brought in by meanders and eddies of the Loop Current, or by upwelling of deeper water at the shelf break. The overall metabolic state of the Gulf Coast is not well constrained, however, with some studies suggesting net autotrophy (in river dominated area) and others implicating net heterotrophy. The net effect of major processes on air-sea CO_2 exchange in the GOM is equivocal, as key identified forcings (river, storm etc.) can potentially drive both super- and undersaturation of surface-water pCO_2. Surface-water pCO_2 data are scarce in the GOM, with the exception of a few studies in the area of the Mississippi River Plume, in the WFS, and a model prediction for the northern GOM. We know of no studies of CO_2 distributions or fluxes in the East Mexico or Campeche-Yucatan shelves.
NOAA will conduct a large scale survey that will include measurements in the GOM and along the southeastern U.S. as well as VOS- and mooring-based CO_2 measurements. We recommend 1) that carbon cycle in various parts of the GOM be studied with a contrast of freshwater and terrestrial material input in mind; 2) that a combined approach of underway shipboard survey, VOS and in situ mooring, and satellite remote sensing be adopted; and 3) that international collaboration with the Mexico partners is necessary.

C.3: Regional Variability of Seawater fCO2 and Sea Surface Temperature (SST) Distributions Along the Pacific West Coast Between 32°N and 5°N

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Catherine Cosca, Pacific Marine Environmental Laboratory, NOAA, Cathy.Cosca@noaa.gov

As part of our continuing effort to understand the regional variability of the seawater fCO_2 and SST distributions of the Pacific West Coast, we deployed automated underway fCO_2 analyzers onboard the NOAA ships *McArthur II* and *David Star Jordon* and the Alpha Ship *Columbus Waikato*. The results indicate strong seasonal variations from 32°N to 16°N, with maximum fCO_2 values occurring during the warm summer months when SST values were highest. Southwest of Baja California there is a strong positive linear relationship between fCO_2 and temperature ($r = 0.72$). However, this relationship does not appear to hold for other coastal regions in the study region farther south. Overall, the region appears to be a strong source for CO_2 to the atmosphere in the northern part of the study area and a strong sink for CO_2 to the south.

C.4: Carbon Sources and Sinks in the Mexican Pacific Coastal Waters

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The measurement of variables related to the CO2 system in Mexican coastal waters has been very scarce and sporadic. Most of the measurements to estimate carbon sources and sinks have been done mainly in two regions: the Gulf of California and the coastal waters off Baja California (Southern portion of the California Current). The subtropical and tropical waters have not been studied. Most of the measurements to estimate the pCO2 in the Gulf of California have done based on measurements of pH, total alkalinity and sometimes also total inorganic carbon. It is until very recently that continuous spatial pCO2 measurements have been done off Baja California. Continuos temporal pCO2 measurements from a buoy off Ensenada, B.C. started also in July 2006. A review of previous and actual measurements of pCO2 is presented for the Mexican Pacific coastal waters.

C.5: Seasonal Variability in Air-Sea Fluxes of CO2 in a River-Influenced Coastal Margin

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A combination of ship-based observations and regional extrapolations using ocean color satellite algorithms provided a basis for spatial and temporal assessments of pCO2 distributions and air-sea fluxes of CO2 in the outflow region of the Mississippi River in the northern Gulf of Mexico. An empirical algorithm was used for assessment of areal

distributions of pCO2 from MODIS imagery. Initial results from June 2003 revealed regions of low pCO2 near the river plume, which would indicate net uptake in those regions and was attributed to a strong river biological pump. Subsequent cruises in August 2004 and October 2005 revealed a different pattern with generally higher levels of surface pCO2. Satellite-derived regional assessments of pCO2 were used in conjunction with estimates of wind fields to produce regional-scale estimates of air-sea fluxes. There was net uptake of CO2 in June, but a net release in August and October. Overall, our results were encouraging for the use of satellite approaches to improve regional assessments of coastal carbon budgets.

C.6: Using Ocean Color to Quantify the Significance of Marine Photochemistry to CO and Carbon Cycling in the South Atlantic Bight

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This work seeks to evaluate the significance of photochemical reactions on carbon cycles, CO2 and CO exchange in the South Atlantic Bight and North American coastal waters using satellite ocean color data and parameterized photochemical efficiency spectra. Estimates for the surface ocean in situ spectral UV radiation field, a critical first step for any photochemical model, are provided over broad spatial and temporal scales by our new SeaWiFS/Modis optical model (SeaUV). Our estimates of the total impact of photochemistry on coastal carbon cycles include (1) direct photo-oxidation of dissolved organic carbon (DOC) to CO2, (2) CO production and loss, and (3) photochemically driven changes in DOC bioavailability defined as moles carbon consumed by the microbial community and designated biologically labile products (BLPs). Using UV attenuation from satellite data together with spectral quantum efficiency data we have previously calculated that about 1/3 of the estimated annual CO2 flux to the atmosphere from the South Atlantic Bight (Cai et al., 2005) could be supplied by direct photochemical CO2 production and up to 40 percent of the annual DOC oxidation could be linked to photochemical processes. We have now combined our previous estimates (using SeaUV applied to SeaWiFS data and best estimates for photochemical efficiency data) with climatological data (temperature, mixed layer depth, wind speed) to provide a closer examination of the South Atlantic Bight over the entire 9 year SeaWiFS data and propose extrapolation of these approaches to evaluate the role of photochemistry in carbon cycling for other coastal systems.

C.7: Carbon Storage in Estuarine Soils of Downeast Maine and the Global C Cycle

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The isotope composition of atmospheric CO2 indicates that the missing C is sinking via a photosynthetic process. However, studies investigating C storage in terrestrial ecosystems have yet to identify the ecosystem(s) where this C is sinking. We hypothesized that much of the missing C is being stored in subtidal and intertidal (non-marsh) estuarine ecosystems. To address our hypothesis, we quantified the organic carbon (OC) from the soil/water interface to 1 m depth in estuary soils representative of the coastal systems on the Atlantic Coast of the North American Continent. The data illustrate that the soils of central Maine's shallow estuaries store as much organic carbon (OC) per hectare as soils in New England's moderately well-drained upland forests. The concentration of stable C and N isotopes in these soils identify that the majority of the OC is fixed by estuarine biota, not upland plants. As sea level rises, the newly fixed OC is buried in the anoxic sediments, which prevents this C from being remineralized and returning to the atmosphere. This result challenges the widely held belief that the OC stored in estuarine sediments has been transported from the surrounding watershed via surface water that has subsequently settled out on the sediment surface. We are looking to partner with C modelers who will help us incorporate the productivity and sequestration of estuarine and coastal systems in global C models.

C.8: An Empirical Study of Climatic Controls on Riverine C export from 3 Major US Watersheds

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The correlations between annual precipitation, evaporation and temperature and annual carbon export (bicarbonate, dissolved organic carbon and particulate organic carbon) are established for the Ohio, Upper Mississippi and Missouri watersheds and coefficients that predict C export based on precipitation, evapotranspiration and seasonal temperature are provided. Carbon export is controlled by the levels of precipitation and evapotranspiration, the precipitation to discharge ratio (P:D), the concentration of the major carbon pool, the rating curve (discharge vs. carbon concentration plots), and seasonal temperature. Within a watershed precipitation has the strongest correlation with annual carbon export for all carbon pools. In the Upper Mississippi and Ohio, levels of evapotranspiration can predict the majority of the residuals of precipitation versus carbon export. Bicarbonate demonstrates the largest response in yield to annual precipitation changes for each watershed. Rating curves, however, indicate that dissolved organic carbon and particulate organic carbon generally increase with increasing discharge, while bicarbonate decreases, causing a larger percentage response to precipitation for the organic carbon pools. Across watersheds the precipitation to discharge ratio is the dominant determinant of how carbon yields respond to changes in precipitation and watersheds with a high P:D ratio should have the largest change in carbon yields with forecasted changes to precipitation. The empirical evidence argues that assuming global warming occurs simultaneously with an accelerated hydrologic cycle, that the hydrologic changes will dominate alterations to carbon yields.

C.9: High frequency CO_2 variability in North American coastal waters

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In 2006, three autonomous pCO_2 systems were deployed on surface moorings in coastal waters representing three very different biogeochemical provinces of the North American coast. One system was deployed off the west coast approximately 84 km northwest of Aberdeen, WA in 132 m of water. This region has a relatively narrow shelf influenced by coastal upwelling and moderate seasonal temperature changes. A second pCO_2 system was deployed approximately 74 km southeast of Savanna, GA in 18 m of water. This mooring, located within the Gray's Reef Marine Sanctuary, is in a region characterized by a broad shallow shelf and somewhat smaller seasonal temperature changes. A third pCO_2 system was deployed in the Western Gulf of Maine near Portsmouth, NH in 65 m of water. This region has a large seasonal temperature cycle and is influenced by seasonal phytoplankton blooms. All three moorings show some degree of diurnal variability, but they have different characteristic variability patterns on timescales of weeks to months. We will compare the time-series records from these three sites and explore the possible mechanisms controlling this high frequency variability.

C.10: Collaborative Carbon Research in the Western Gulf of Maine

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We highlight our group's observational and research efforts towards understanding the cycling of carbon in the western Gulf of Maine, a temperate coastal margin ecosystem with substantial riverine influence. Optical, trace gas, organic and inorganic carbon measurements from monthly cruises, and continuous carbon dioxide monitoring, reveal relationships between the optical parameters, riverine fluxes and metabolic status of the system. These relationships are being exploited to extend the use of satellite data in conjunction with circulation modeling for estimating and identifying sources and sinks of organic and inorganic carbon.

C.11: Carbon metabolism in a temperate coastal, river ecosystem

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The transformations and transfer of organic and inorganic carbon between terrestrial and marine coastal systems is an important part of the global carbon cycle that has been not well characterized. Primary factors driving ecosystem carbon metabolism include temperature, phytoplankton biomass, primary production, and dissolved organic matter. These can be detected or determined from satellite remote sensing, making it possible that system respiration can be derived from these factors with enough information about their relationships. We study the production (respiration) and consumption (primary production) of CO2 in the Androscoggin/Kennebec River plume as it enters Gulf of Maine waters over the seasonal cycle. Carbon species and the plankton community structure are characterized, and rates of primary production and respiration in the surface water are measured at 5 stations monthly. Results from 1.5 years reveal strong seasonal signals, relationships to river flow rates, and consequent changes in plankton community structure that all influence system metabolism. The system is predominantly productive with primary production exceeding respiration most times and places.

C.12: Autonomous carbon dioxide measurements of air-water and horizontal atmospheric fluxes at the continental boundaries

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A primary objective of the North American Carbon Program (NACP) is the detection and attribution of fluxes from terrestrial and continental margins of North America. A necessary component of this NACP goal is the development of a network of autonomous measurement systems that capture carbon dioxide transport in both coastal and riverine environments. These wet regions require remote observations. Offshore sites provide the opportunity to create fence posts around the continental boundary that are largely unaffected by local terrestrial point sources. Three new prototype sites, which demonstrate how autonomous carbon dioxide systems may be used to understand and monitor transport on local to regional scales at continental boundaries, will be presented. While offshore, coastal measurements can provide accurate carbon dioxide at the continental boundaries representative of large source areas, river flux sites help to understand small-scale sources and sinks.

C.13: Coastal CO2 Measurements and Databases for the North American Carbon Program: East Coast and Gulf Coast

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As part of NOAA's commitment to the NACP Coastal Ocean Carbon Project a research cruise is planned on NOAA ship Ronald H. Brown for July 2007 that covers the East Coast of the US and Gulf of Mexico. The cruise has as overriding aim to provide a semi-synoptic picture of pCO2 in air and water, and CO2 fluxes along the Gulf and East Coast to determine the effect of the coastal ocean on continental mass balances of carbon. A companion cruise is planned for the West Coast for the same time period. Supporting objectives in this endeavor are to estimate air-sea fluxes through direct micrometeorological measurements; to delineate hydrographic/biogeochemical regimes along the coast and determine parameters to assist in this delineation; to improve process level understanding of controls of pCO2 in coastal waters; and to assess possibilities of utilizing remote sensing to create air-sea CO2 flux maps in the coastal ocean. The effort also aims to initiate integration of the myriad of high quality coastal observations and process studies that have been performed at local scale to obtain a holistic view of the critical processes controlling ocean carbon dynamics along East Coast and Gulf Coast of the USA.

C.14: Estimating the photochemical oxidation of carbon to CO2 on the continental shelf of the Eastern United States

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The spatial distribution and variability of carbon sources and sinks at regional to global scales is far from being precisely quantified. Here we attempt to estimate the production of carbon dioxide (CO2) generated by photooxidation of organic material in surface waters of eastern U.S. continental shelves influenced by riverine discharge. Large amounts of carbon as dissolved organic carbon (DOC) are annually transferred from continents to the ocean through rivers. In coastal environments influenced by riverine discharge, a significant fraction of the DOC, the chromophoric dissolved organic matter (CDOM), is capable of absorbing visible light and hence can be detected by ocean color satellite sensors. Significant photochemical loss of CDOM absorption occurs in surface waters of the Middle Atlantic Bight (MAB) during summertime stratification and it has been shown that photoxidation of carbon to CO2 (~ 15 % of total carbon) occurs concomitant to ~ 100% loss of color (or CDOM absorption). To explore the extent of photochemical oxidation of carbon to CO2 on continental shelves, we converted monthly composites of SeaWiFS data of normalized water-leaving radiance to CDOM absorption. From the CDOM monthly composites, we estimate changes of CDOM absorption coefficient in surface waters across the shelf over the summer relative to the springtime (uniformly mixed water column prior to photobleaching) and to the fall (uniformly mixed water column following photobleaching) thus providing estimates of the spatial CDOM absorption deficits caused by photobleaching. We used published relationships between absorption loss and CO2 photoproduction to convert these absorption deficits to estimates of photochemical oxidation of carbon to CO2. Our preliminary work shows (i) that the seasonal change in CDOM absorption attributable to photobleaching is evident in the ocean color measurements; (ii) that the Johannessen et al. algorithm closely estimates our in situ data on the MAB; (iii) and that CO2 photoproduction can be estimated from the absorption deficit observed in surface waters by the ocean color measurements.

Tuesday, January 23

Mid-Continent Intensive Study

D.1: LiDAR and Biometry-based Estimates of Carbon Pools and Fluxes at Landscape Scales

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Many models of landscape to global carbon cycling are based in part on digital maps of land cover and vegetation structure. Errors in these models introduce errors in predicted carbon dynamics. We describe the combination of high resolution spectral and lidar (laser detection and ranging) data to estimate vegetation type and structure in a northern forest/wetlands complex. Vegetation type and structure from spectral/lidar data to moderate resolution data, and to field observed vegetation type and structure and ground truth

sites. Further, we compare estimates of carbon fluxes, derived from field estimates of representative stands, to those based on control, moderate resolution spectral data, and high resolution spectral and spectral/lidar data. Spectral/lidar data are significantly more accurate, based on Cohen's K, and yield different net woody carbon gain estimates than maps derived from moderate-resolution spectral data.

D.2: Campaign CO2 measurements in support of the North American Carbon Program Midcontinental Intensive regional experiment: The Second "Ring of Towers"

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A central barrier preventing the scientific community from understanding the carbon balance of the continent is methodological; it is technically difficult to bridge the gap in spatial scales that exists between the detailed understanding of ecological processes that can be gathered via intensive local field study, and the overarching but mechanistically poor understanding of the global carbon cycle that is gained by analyzing the atmospheric CO2 budget. The NACP's Midcontinental Intensive (MCI) study seeks to bridge this gap by conducting a rigorous methodological test of our ability to measure the terrestrial carbon balance of the upper Midwest. A critical need in bridging this gap is increased data density.
Our work will add a regional network of five communications-tower based atmospheric CO2 observations from April, 2007 through October, 2008 to the planned long-term atmospheric CO2 observing network (tall towers, aircraft profiles, and well-calibrated CO2 measurements on AmeriFlux towers) in the midcontinental intensive region. A primary goal of the project is to increase the regional atmospheric CO2 data density so that 1) atmospheric inversions can derive well-constrained regional ecosystem carbon flux estimates and 2) the trade off between data density and accuracy of the flux estimates can be determined quantitatively using field observations, thus providing guidance to future observational network designs.
This work builds upon the success of the first ring of towers, deployed as part of the ChEAS in northern Wisconsin. We present results from this first ring, in addition to observation and analysis plans for the second ring.

D.3: Investigation of Carbon Cycle Processes within a Managed Landscape: Recent Progress and Future Research

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Our research is designed to improve the scientific understanding of how carbon is cycled between the land and atmosphere within a heavily managed landscape that is characteristic of the Upper Midwest. In this poster presentation we present key results from experiments conducted from 2002 to present and outline future research plans. Our results focus on: 1) The impact of land management on the long-term (~5-year) carbon balance of agricultural ecosystems; and 2) Development and implementation of micrometeorological and stable isotope techniques to trace the flow of carbon between land and atmosphere at a variety of temporal and spatial scales.
1. Near-continuous eddy covariance flux measurements have been made in conventional and alternative corn-soybean rotation systems since 2002 to evaluate their carbon sequestration potential. The alternative land management system consists of fall strip tillage combined with a spring and/or fall cover crops. The first complete biennial rotation (2001 through 2003) revealed that both systems were a small net loss of approximately 90 g C m-2 to the atmosphere indicating that modified tillage practices and the use of a spring oats cover crop had little or no impact on enhancing carbon sequestration. However, experiments involving a winter rye cover crop planted during fall 2004 resulted in an additional 175 g C m-2 y-1 (fall 2004 to fall 2005) relative to the conventional treatment. But what are the potential longer-term feedbacks of increased carbon inputs? Preliminary analyses of flux data collected during the following year (fall 2005 to fall 2006) indicate a substantial enhancement (about 40%) ecosystem respiration as microbial activity adjusted to the added substrates. From a greenhouse gas management perspective, these preliminary findings suggest that the initial carbon gain from cover cropping could be used more effectively as an alternative fuel source (i.e. Ethanol production) rather than attempting to rebuild soil organic matter, which is a relatively slow and inefficient process when considering the immediate need to lower atmospheric carbon.
2. The stable isotope composition of CO2 in the atmosphere represents a potentially important signal of global change. Interpreting its variation, however, requires a sound understanding of the underlying biophysical processes. This ultimately requires improved ability to quantify isotopic fluxes between the land and atmosphere. We have conducted carbon isoflux experiments using tunable diode laser isotope systems combined with both flux-gradient and eddy covariance theory. The high temporal resolution of the CO2 isotope signals is providing new insights as to how photosynthetic discrimination and heterotrophic and autotrophic respiration vary with time and impact the isotopic composition of the atmosphere. These new data should lead to a better understanding of how climate variations and changes in land use impact the partitioning of net CO2 exchange. Our poster will highlight some of these results at the ecosystem scale and our plans for extending these new techniques to a tall tower (240 m) site to gain a greater understanding of carbon cycling processes at the landscape scale.

D.4: Using remote sensing and a biogeochemical process model to estimate productivity of complex forested ecosystems in support of the NACP Mid-Continent Intensive

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The WLEF tall tower near Park Falls, Wisconsin, is the only long-term tall tower being used as part of the NACP Mid-Continent Intensive. Therefore, scaling tower results to the regional level is vital for comparison against other methods (e.g., remote sensing) of obtaining the carbon balance. We use the Biome-BGC ecosystem process model over the tower footprint to test the model's ability to capture the dynamics of this complex system, composed of 30% wetlands. Results suggest that the Biome-BGC model is inadequate for estimating the carbon balance of the wetlands in this area. We test two versions of Biome-BGC developed for wetlands to ascertain if this will improve model results. Our tests indicate that adding wetlands to the model improves comparisons, suggesting that a modified Biome-BGC can be used in complex ecosystems.

We then test the ability of the Moderate Resolution Spectroradiometer (MODIS) onboard NASA's Terra satellite to simulate the gross primary production (GPP) of this ecosystem. The MODIS GPP light-use efficiency algorithm has no mechanism for restricting growth in wetlands through driving variables such as soil temperature and surface water depth. Using observations from Lost Creek, an eddy covariance flux tower in a nearby shrub wetland, we evaluate uncertainties associated with the MODIS GPP and a modified algorithm that includes key environmental constraints to wetland vegetation. Differences in model logic are discussed with respect to uncertainties in regional estimates of terrestrial plant growth and production in the Great Lakes Region, where wetlands can comprise one-third of the landscape.

D.5: Effects of Topography and C4- vs. C3-Sourced Carbon on the Rate of Soil Carbon Accrual in Restored Midwestern Grassland

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Conversion of cultivated and other degraded soils back to perennial grassland, including switchgrass for biofuels production, has the potential to restore depleted soil organic matter stocks and serve as a sink for rising atmospheric CO_2 concentrations. For the last three decades, a chronosequence of restored prairies at the Fermi National Accelerator Laboratory near Batavia, IL has been accumulating soil C, but the mechanisms controlling the rate of accrual and potential saturation of the system are not yet clear. This study used a repeated measures approach rather than the chronosequence method to determine the rate of soil C accrual for each of four restored prairies (dominated by a mixture of native C4 grasses including switchgrass) and a field of smooth brome, an introduced C3 grass. Stable C isotope signatures were used to determine accumulation rates for C4- and C3-sourced C. Fifteen to 30 years after planting, prairies located in topographically lower areas appeared to have a faster rate of C accumulation compared to topographically higher prairies, but the brome field remained at steady state with respect to soil C. Soil organic matter stabilization in these highly structured soils may be enhanced by periodic microclimatic conditions that inhibit C mineralization during the longer periods of seasonally flooded conditions in the low lying prairies. The prairies that exhibited the fastest C gain had the greatest increases in C4-C, which was not necessarily related to biomass of C4 plants. The lower quality of organic inputs from prairie plants, especially C4 grasses, compared to brome and other C3 species may lead to faster and more sustained C accumulation.

D.6: Carbon Sequestration Potential in Midwest Agricultural Land and Restored Grasslands (Fermiflux) study

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Two new AmeriFlux sites started measuring CO_2 and energy fluxes at the Fermi National Environmental Research Park in the Midwestern United States, a region previously identified by the NACP as needing increased coverage. The AmeriFlux towers are located on (1) cultivated land under soybean-corn rotation, with conservation tillage management of the soil, and (2) long-term-cultivated land restored to native vegetation that undergoes fire treatment every other year. Both sites are highly representative of current management practices in the Midwest. Conservation tillage (no tillage after soybean crop) is used in 45% of the area comprising the U.S. Corn Belt. The restored land at Fermilab represents management practices applied under the CRP. At the prairie site, we expected increases in plant productivity and high NEE during 2005 as a result of fire treatment. However, plant biomass in 2005 was similar to 2004 and lower than in 2006. This could be caused by the extremely dry conditions plants experience during the growing season of 2005. Nevertheless, NEE was 140 g C m^{-2} higher in 2005 compared to 2006 when an invasive specie, *Melilotus alba* (M.), greatly affected ecosystem fluxes. Biometric and annual NEE estimates of NEP correlated extremely well at the prairie site, resulting in 5.5 Mg C $h^{-1}y^{-1}$ in the year 2005. About 14% of NEP remained in the soil each year, with climate and vegetative growth exerting the greatest controls on C sequestration. Our results will (1) reduce uncertainty about belowground C cycling and its magnitude, (2) indicate the potential of restoration practices as C sequestration strategies, and (3) produce data to constrain models.

D.7: Full carbon accounting for carbon management options on US croplands: A framework and tool for decision-making

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To effectively support climate policy and carbon management decisions, it is important to understand and quantify the interactions and feedbacks between policies and management options that impact carbon fluxes. Our research efforts aim to improve our ability to quantify these interactions and to improve the spatial resolution of carbon fluxes related to US croplands. We have developed an accounting framework using integrated field, inventory, and remote sensing data coupled with an agricultural economics and land-use model. Our method of spatially explicit, full carbon accounting currently uses 3,037 crop budgets that represent eight major crops, three tillage intensities, and numerous combinations of crop rotations and production inputs. The complete framework and accounting tool can provide estimates of net carbon flux associated with different policy decisions and economic incentives. Preliminary analyses conducted in the US Midcontinent region indicate that there has been a net cumulative soil carbon increase of 57.3 Tg C between 1991-2000. This estimate is based on the initial soil carbon content, production inputs, crop, tillage, and current land management strategies. Annual changes in soil carbon and carbon emissions from fossil-fuel use can change significantly each year due to crop rotations and increases or decreases in the land area that is using different carbon management strategies. We quantify and illustrate these annual changes at a 30m x 30m resolution and discuss the potential contributions of this newly developed accounting framework.

D.8: The Bondville Intensive: An Integrated, Bottom-Up Approach to Estimating Regional Fluxes

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Starting in the summer of 2005, this intensive campaign was developed to test a number of different approaches to scaling carbon, water, and energy fluxes over agricultural landscapes. This campaign takes place in Champaign County, Illinois over a soy/maize agroecosystem. The approaches vary from direct measurement and scaling using land cover maps, to remote sensing approaches using hyper- and multi-spectral methods. Measurements were simultaneously taken at leaf, plant, tower (field), aircraft (sub-regional), and satellite (regional) scales. These high resolution co-located data sets are currently being used to populate models and compare different approaches for estimating fluxes at several scales. While temporal data are being collected at tower sites throughout the year, most of the additional data has been collected during the growing season, between June and September. Preliminary analyses indicate strong between several of the methods.

Managed Forests and Woodlands

E.1: Disturbance, Succession, and Forest Carbon Storage: Re-Examining Odum's Theory of Ecosystem Development With the Tools of Fluxnet

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Direct measurements of carbon fluxes from the soil through to the lower atmosphere have led to new insights into how disturbance, succession, and climate change simultaneously constrain the carbon storage capacity of forested ecosystems. In 1969, Eugene Odum hypothesized that forest net ecosystem production follows a sinusoidal pattern with stand age, with an initial post-disturbance reduction in carbon storage followed by a climax at maximum canopy assimilation and then a drop in storage that stabilizes with forest maturation. How well do Odum's predictions match results from contemporary carbon cycling studies?
At the University of Michigan Biological Station Forest Carbon Cycle Research Program we have traced the historical legacy of clearcutting and wildfire on forest carbon cycling in northern lower Michigan and documented how climatic variability currently constrains carbon storage in these ecosystems. Annual carbon storage averaged 1.52 Mg C ha-1 between 1999 and 2003, and varied interannually with soil temperature and cloud cover. Repeated harvest and disturbance by fire has reduced the carbon uptake capacity in experimental plots by 45% relative to controls. We also have initiated a new ecosystem-scale experiment to directly examine disturbance, age, and species diversity effects on forest-atmosphere exchanges of mass and energy. We hypothesize that succession to an uneven-aged, more biotically diverse forest will increase carbon storage relative to the existing late-successional aspen-dominated forest. Odum's seminal work continues to provide a solid theoretical foundation for our studies.

E.2: The Effect of Intense Wildfires on Ecosystem Gas Exchange of Ponderosa Pine Forests in Northern Arizona

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Fire is a dominant control on the carbon balance of forested landscapes. It volatilizes large amounts of stored carbon and mineral nutrients, removes photosynthesizing leaf area and triggers CO_2 loss due to the creation of debris subject to decomposition, changing a forest ecosystem from a sink to source of CO_2. The fire effects can last for variable periods, depending on the intensity of the fire and the system resistance and resilience to this disturbance. Fire suppression has had profound effects on ecosystems in the Southwestern USA, where forests are now often very dense and subject to highly destructive fires. Recovery of trees in Southwestern ponderosa pine forests is known to be slow, because of infrequent suitable conditions for regeneration and because of difficult climatic conditions, characterized by cold winters, dry spring and fall, and unpredictable precipitation. Consequently, models of ponderosa pine forests and empirical results from other areas are difficult to apply to forests in the northern Arizona. To improve understanding of the effects of fire in northern Arizona we compare an unmanaged ponderosa pine forest and a forest burned by a stand-replacing wildfire in 1996. 10 years after the fire, compared with the unburned site, the burned site comprised only herbaceous plants and sparse shrubs, has lower overstory basal area (30 vs. 0 m^2ha_{-1} respectively), total LAI (2.3 versus 0.6 m^2m_{-2}), canopy height (18 vs. <0.5 m). One year of continuous net ecosystem exchange measurements using the eddy covariance technique shows different level of energy absorbed and made available to the ecosystem, and differences in energy partitioning. Rates of ecosystem CO_2 exchange were lower in the fire site, and the CO_2 uptake was limited to a shorter period, making the burned stand a source of CO_2, whereas the unburned forest site was a net CO_2 sink.

E.3: Carbon flux associated with management and disturbance along an urban to rural gradient: Baltimore, MD to the New Jersey Pine Barrens.

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This research examines the carbon dynamics associated with major natural and anthropogenic disturbances. Carbon flux measurements and carbon dioxide concentrations were taken along an urban to rural gradient from Baltimore, MD, to the New Jersey Pine Barrens. The gradient incorporates natural disturbances and management in forested lands and heavily vegetated "non-forest" urban areas. The three towers in the Pine Barrens of NJ, monitors carbon flux under prescribed burning/fire management and disturbance, going from a mixed overstory oak forest in the west, to a mature oak and pitch pine association found at this central site, to a mature pitch pine - scrub oak vegetation in the eastern Pine Barrens. The Cub Hill tower in Baltimore, MD, monitors carbon dioxide concentrations and carbon flux from a deciduous overstory found in a residential area of Baltimore. Disturbances found in these urban and rural ecosystems includes the effects of anthropogenic cycles associated with the work week, prescribed burning, gypsy moth outbreak, climate variability and land use change.

E.4: The Kane Experimental Forest Carbon Inventory: A Case Study Using FVS Carbon

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As the number of state and regional climate change agreements grows, so does the need to assess the carbon implications of planned forest management actions. At the operational level, producing detailed stock estimates for the primary carbon pools becomes time consuming and cumbersome. FVS Carbon is a new tool that is fully integrated within the Forest Vegetation Simulator, allowing users to produce carbon reports along with traditional FVS output. This added capability can be used by managers familiar with FVS and requires just a few additional keywords. All methodologies and computations are consistent with Intergovernmental Panel on Climate Change and US standards. In this paper we present a current carbon inventory for the Kane Experimental Forest, a 1,737 acre Allegheny hardwood forest located in northwestern Pennsylvania. Future carbon stocks are also projected using the new carbon budgeting capabilities of FVS. Practical considerations to consider when planning and implementing carbon budget analyses using FVS are also discussed.

E.5: Carbon Dioxide and Methane Fluxes in Disturbed Southwestern Ponderosa Pine Forests

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The overall goal of our research is to characterize the effect of disturbances by forest management and wildfire on fluxes of carbon dioxide (CO2) and methane (CH4) between the atmosphere and land in ponderosa pine-dominated forests of northern Arizona. In 2005 we established intensive research sites in three stands that represent the most common forest conditions in ponderosa pine forests of the southern Colorado Plateau: 1) an unmanaged stand with no recent thinning or prescribed burning, 2) a stand that was recently (October 2006) treated with operational restoration forest management (thinned and prescribed-burned), 3) a stand that was severely burned by wildfire in 1996. The specific objectives of our research are to: a) compare atmosphere-to-land CO2 flux and its partitioning into above- and below-ground components among stand types, b) compare atmosphere-to-land CO2 flux measured by the tower-based eddy covariance approach with ground-based estimates of net ecosystem CO2 production (NEP) using the biomass inventory approach (net primary productivity minus heterotrophic respiration), c) compare soil flux of CH4 among stand types, d) assess influences of weather and climate factors on CO2 and CH4 fluxes, e) evaluate the influence of forest management treatment and wildfire on partitioning of energy into latent and sensible heats. Flux measurements were started in 2005, one year prior to the restoration thinning treatment. We present an overview of the project, preliminary results based on pretreatment data, and future plans for the project.

E.6: North American Forest Disturbance Patterns Assessed from LEDAPS Satellite Analysis

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Stand clearing disturbances (harvest, fire) are thought to play a major role in controlling land-atmosphere fluxes of carbon. In support of the North American Carbon Program, the LEDAPS (Landsat Ecosystem Disturbance Adaptive Processing System) has been analyzing the Landsat satellite record to assess rates of forest disturbance across North America. Wall-to-wall Landsat coverage for the period 1975-2000 has been converted to surface reflectance and analyzed for decadal losses (disturbance) or gains (regrowth) in biomass using a spectral "disturbance index". Preliminary (unvalidated) results for the 1990's indicate high rates of harvest within the southeastern US, Eastern Canada, and the Pacific Northwest, with spatially averaged (~50x50 km) turnover periods as low as 25-40 years. Lower rates of disturbance are found in the Rockies and Northeastern US. Validation of these results relies on visual analysis of image subsets and comparison with FIA data. This presentation will give an overview of the LEDAPS processing and validation efforts, present recent results, and discuss lessons learned for large area analyses using high-resolution satellite data.

E.7: Effects of Free-Air-CO2-Enrichment (FACE) on fine root production and soil fungi in a loblolly pine plantation over a six year period

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Efforts to characterize carbon cycling among atmosphere, forest canopy, and soil carbon pools are hindered by a poorly quantified fine root dynamics. We characterized the influence of free air CO2-enrichment (ambient + 200 ppm) on fine roots for a period of 6 years (Autumn 1998 through Autumn 2004) in an 18 year old loblolly pine (Pinus taeda) plantation near Durham, NC (USA) using minirhizotrons. Root production and mortality were synchronous processes that peaked most years during spring and early summer. Seasonality of fine root production and mortality was not influenced by atmospheric CO2 availability. Averaged over all six years of the study, CO2 enrichment increased annual fine root standing crop (+23%), annual root length production (+25%), and annual root length mortality (+36%). Larger increase in mortality compared to production with CO2 enrichment is explained by shorter average fine root lifespans in elevated plots (500 days) compared to controls (574 days). The effects of CO2-enrichment on fine root proliferation tended to shift from shallow (0-15 cm) to deeper soil depths (15-30) with increasing duration of the study. Diameters of fine roots were initially stimulated by CO2-enrichment but this effect diminished over time. Averaged over six years, annual fine root NPP was estimated to be 163 g dw m-2 yr-1 in CO2 enriched plots and 130 g dw m-2 yr-1 in control plots (P = 0.13) corresponding to an average annual additional input of fine root biomass to soil of 33 g m-2 yr-1 in CO2-enriched plots. A lack of consistent CO2 x year effects suggest that the positive effects of CO2 enrichment on fine root growth persisted six years following minirhizotron tube installation (8 years following initiation of the CO2 fumigation). Although CO2-enrichment contributed to extra flow of C into soil in this experiment, the magnitude of the effect was small suggesting only modest direct contributions to soil C storage in Southeastern pine forests. Effects of CO2-enrichment on soil fungi will also be discussed.

E.8: Effects of wildfire on soil carbon dioxide and methane fluxes in a Southwest, U.S. ponderosa pine forest

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Soils are significant sources and sinks of the greenhouse gasses carbon dioxide (CO_2) and methane (CH_4). Forest soils release CO_2 because of soil microbial and plant metabolic respiration. Well-aerated forest soils take up CH_4 because of metabolism by methanotrophic bacteria in the soil. Intense wildfire is an increasingly common disturbance to ponderosa pine forests, yet understanding of fire's effects on greenhouse gas fluxes from soils is poor. The objectives of this research are to explore how wildfire affects fluxes of CO_2 and CH_4 from soil in ponderosa pine forests on the Colorado Plateau in Northern Arizona. We compare soil gas fluxes in a dense forest (unburned control site) to a previously forested site that burned catastrophically in 1996, killing all trees (fire site). We use two CO_2 measurement techniques: 1) a static chamber technique with gas chromatography and 2) a diffusion gradient technique using small buried infra-red gas analyzers. CH_4 is concurrently measured with CO_2 using the static chamber technique. During the 2006 growing season, soil CO_2 flux was significantly higher at the control than at the fire site. Soil CH_4 uptake was significantly higher at the fire site than at the control. Temporal and site differences in CO_2 and CH_4 fluxes are explained partly by soil water content, soil temperature, and stand characteristics such as leaf area index. Our results indicate that wildfire disturbance must be considered for accurate regional assessments of soil fluxes of CO_2 and CH_4 in Southwestern ponderosa pine forests.

E.9: Effects of Insect Defoliation on Regional Carbon Dynamics of Forests

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On an annual basis, insects severely defoliate more than 20 million acres of forested land in the conterminous United States, affecting a larger area and incurring higher economic costs than any other disturbance. However, the long-term costs and ecosystem consequences of insect outbreaks on forest productivity are difficult to quantify at the regional scale because of the variety of pests involved, differences in forest types affected, and varying spatial scale and intensity of the impacts. In our research, we are developing estimates of defoliation extent and intensity, as measured through seasonal losses in leaf biomass and changes to forest productivity derived from Terra MODIS imagery. We identify characteristic trends in land surface phenology associated with defoliation that can be applied across years to map defoliated areas and resulting declines in forest productivity. We use field data in conjunction with Landsat and aerial imagery and outputs from models of insect population dynamics (BioSim) to either calibrate or validate our remotely sensed estimates. Finally, the results of the remote sensing work are used to drive LANDIS-II, a spatially explicit forest simulator capable of modeling insect impacts on forest biomass and successional dynamics.

Arctic and Boreal Ecosystems

F.1: Trends in satellite observed North American photosynthetic activity since 1981

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Temperature increases in the northern high latitudes over the past few decades have led to a wide variety of ecosystem changes, including modification of the productivity of plants as measured by ground cover (growth) and associated changes in global CO2 exchange. Well-known studies of "greening" trends in high latitude vegetation since 1981 indicate an earlier onset of growing season and more active photosynthesis in the mid-summer months. Our work, based on the most recent AVHRR-NDVI time series data sets, indicate that these trends did not continue uniformly in time or space but instead varied between vegetation types and periods of the growing season. We documented different responses of vegetation to temperature and precipitation, including lagged responses to conditions of the previous growing season. The results indicate that some high latitude forest areas have declined in photosynthetic activity associated with warming and drying, whereas most tundra areas have experienced systematic greening. The satellite observations are increasingly supported by a range of field measurements that together indicate these ecosystems are responding to the recent changes in climate. Although the observational time scales are not as long as hoped, the responses have been rapid. Woody shrub growth in tundra areas has increased and tree ring growth in some boreal regions has declined in

recent years. The latter indicates "browning" in response to physiological temperature thresholds and temperature-induced drought stress. We are further documenting these relationships and exploring the association between satellite-based metrics of vegetation activity and a suite of in situ observations.

F.2: Effects of wildfire and climate on northern Manitoba, Canada

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The goals of this study were to simulate the effects of changing climate, CO2 and wildfire on the structure and carbon balance (net biome production, NBP) 100 MHa in the central Canadian boreal forest from 1948 to 2005. Simulations were run using the Biome-BGC process model and included (i) explicitly simulated (and interacting) C, N, and water cycles; (ii) a Farquhar photosynthesis model sensitive to environmental and physiological parameters; (iii) dynamic and competing vegetation types; and (iv) explicit spatial representation of a large (~20% of the North American boreal forest) landscape at a high level of detail (1 km2 cell size). Simulation results indicated that the region lost on average 226 g C m-2 over the past 58 years, relative to what would have happened if mid-century conditions had continued unaltered, with the difference increasing in recent years. The major and consistent driver of NBP was fire disturbance, while climate change increased the NBP variability. The NBP of well-drained areas was significantly more variable than that of poorly-drained areas. Total net primary production (NPP) averaged 187 g C m-2 yr-1, was dominated by conifers, and dropped with time, even as NPP of deciduous trees and bryophytes increased.

F.3: The effects of burning of deep organic soils in North American boreal forests and peatlands on emissions and the terrestrial carbon budget

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Our NACP project is focused on examining how fuel consumption varies in the deep surface organic layers found in many boreal forests and peatlands across in western North America, and analyzing how the factors controlling the variations in fuel consumption influence inter-annual to decadal variations in the North American terrestrial carbon budget. In this poster, we will present the results through year 2 of this 3-year project, which include: (a) an analysis of longer term variations in the fire regime across the North American boreal forest; (b) an assessment of using satellite imagery to assess spatial variations in fire severity; (c) collection and analysis of field measurements on the patterns of organic layer depth reduction and carbon release during fires in black spruce forests in interior Alaska; and (d) the incorporation of a boreal fire fuel consumption model with the Terrestrial Ecosystem Model. We will also present our plans for the third year of our study, which will focus on documenting the extent of fire in peatland complexes in western North America as well as field observations of fuel consumption in these peatlands.

F.4: Carbon Fluxes From Canadian Forests and Peatlands: the Fluxnet-Canada Perspective

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The potential importance of the biosphere to climate change is highlighted by the fact that annual C fluxes from terrestrial ecosystems are an order of magnitude greater than fossil fuel emissions. Canada's vast land area provides us with both a national opportunity and a global responsibility to understand, manage, and predict the role of our terrestrial ecosystems in climate change.
By March 2007 the Fluxnet-Canada Research Network will have been in operation for five years and conducted carbon flux measurements at a total of 36 network or associated sites along an east-west continental transect. Year-round measurements of the net exchange (flux) of C, water and energy between these sites and the atmosphere will have been made at 26 of these sites, while the other ten sites will have been measured periodically during the growing season. The network studies a) the relationship between the inter-annual variability of C fluxes and climate, b) the effect of disturbance on C fluxes, c) the relationship between ecosystem productivity and net C fluxes, and (d) ecosystem and climate models that allow extrapolation in space and time. The knowledge gained from these studies will allow us and others to provide better estimates of the potential for C uptake, emission and long-term sequestration by Canadian forests and peatlands. We will present key results from the network.

F.5: Characterization of frozen and thawed seasons in the terrestrial high latitudes with spaceborne microwave remote sensing: Relationships with land-atmosphere CO2 exchange

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Landscape transitions between seasonally frozen and thawed conditions occur each year over roughly 50 million square kilometers of Earth's Northern Hemisphere. These relatively abrupt transitions represent the closest analog to a biospheric and hydrologic on/off switch existing in nature, affecting surface meteorological conditions, ecological

trace gas dynamics, energy exchange and hydrologic activity profoundly. We utilize time series satellite-borne microwave remote sensing to examine spatial and temporal variability in seasonal freeze/thaw cycles for the pan-Arctic basin and Alaska. Regional measurements of spring thaw and autumn freeze timing are derived using daily brightness temperature measurements from the Special Sensor Microwave Imager (SSM/I) and the SeaWinds-on-QuikSCAT scatterometer. We examine relationships between freeze/thaw timing as related to sensor, satellite overpass time, and landcover, and in relation to regional biospheric activity indicated by atmospheric CO2 measurements. Spatial and temporal patterns in regional freeze/thaw dynamics show distinct differences between North America and Eurasia, and boreal forest and Arctic tundra biomes. Annual anomalies in the timing of thawing in spring also correspond closely to seasonal atmospheric CO2 concentration anomalies derived from NOAA CMDL arctic and subarctic monitoring stations.

F.6: A Wetlands Map of Alaska Using L-Band Radar Satellite Imagery

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Wetlands act as major sinks and sources of greenhouse gases, and can switch from sink to source in response to climatic and anthropogenic forces that are poorly understood. Northern peatlands, in particular, are believed to have hitherto served as important carbon sinks, sequestering about 1/3 of the total global pool of soil carbon. Despite their importance in the carbon cycle, the locations, types, and extents of northern wetlands are not accurately known. L-Band synthetic aperture radar (SAR) imagery is well suited to the task of identifying and classifying wetlands. Since L-Band SAR is sensitive to vegetation structure, biomass, and moisture content, it is capable of distinguishing the distinct scattering characteristics of the various wetlands classes. We are using multi-temporal L-band SAR imagery to produce a thematic map of wetlands throughout Alaska. The classification is based upon a decision tree algorithm called Random Forests. Random Forests operates by first randomly generating a large number of decision trees, a "forest", based upon training data of known characteristics. It then classifies each image pixel outside the training set by implementing all decision trees in the "forest" and setting the pixel class equal to the class selected by a plurality of the decision trees. This approach has been found capable of distinguishing as many as four different aggregate wetlands classes plus one generic uplands class with classification accuracies of better than 75%.

F.7: Rates and Effects of Climate Warming and Permafrost Thawing in the Yukon River Basin: An Integrated Approach to Tracking Carbon Flux

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Permafrost has begun to thaw beneath many parts of the Boreal Forest, exposing large quantities of carbon (C) stored in ancient, frozen organic materials to decomposition or erosion. The potential consequences of the release of this carbon, such as accelerating greenhouse gas accumulation in the atmosphere or changing the nutrient balance of the coastal ocean, are largely unknown. A developing consortium of US and Canadian federal agencies, university scientists, and tribal organizations is implementing a monitoring and research strategy that will link air, water, soil, and forest information across the Yukon River Basin. Research in the watershed during 2000-2005 showed that changes in hydrology (decreased flow) and river water-quality (decreased dissolved organic carbon) are already occurring. Evidence of widespread permafrost thawing and the associated enhanced infiltration of water into watershed soils have also been documented. Preliminary research on C flux to the atmosphere in landscapes with thawing permafrost indicates enhanced methane release associated with the development of "thermo-karst" topography where permafrost has degraded. The Yukon Basin assessment and monitoring network will link research on the effects of fire, soil moisture, vegetation, gas flux, and hydrology with regional surveys of key indicators of C dynamics and recent advances in remote sensing methodology. The combined, multi-scale dataset will be used to improve and constrain the Terrestrial Ecosystem Model (TEM) and General Ensemble Modeling System (GEMS), which in-turn will be used to estimate C flux and storage in the Yukon River Basin. The assessment will provide a comprehensive, integrated estimate of the carbon, water, and energy budgets for the Boreal landscape by using the Yukon river basin as a common frame of reference, and will establish a systematic network for multi-scale tracking of environmental change as the northern landscape responds to a changing climate.

F.8: Interannual Variability of Primary Production in the Arctic Ocean

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Effects of rapidly changing climate on the biogeochemical fluxes in the Arctic Ocean have yet to be fully assessed. An important step towards better understanding of the effects of environmental changes on marine ecosystem and carbon biogeochemistry is to quantify basin-scale rates of primary production. A number of primary productivity estimates are

already available, however these cover relatively small temporal and spatial scales due to the difficulty of sampling such a harsh and often inaccessible environment. In order to evaluate the effects of ongoing changes in the Arctic marine environment, we analyzed interannual changes in primary production over the entire Arctic Ocean between the years 1998 to 2006. For this purpose, we used satellite-derived chlorophyll a, sea surface temperature, and photosynthetically available radiation as input to a bio-optical model of primary productivity. Changes in sea-ice during this period were quantified using data from satellite microwave sensors. Interannual changes in primary productivity were assessed while accounting for the dramatic changes of sea-ice covered area. The contributions of different geographical regions and ecological regimes to pan-Arctic primary-production were also investigated in order to compare regions and ecosystems that are changing at different rates.

F.15: Impacts of Soil Freeze/Thaw Dynamics on the North American Carbon Cycle

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Between 68 and 80 percent of North America experiences seasonal freezing and thawing with the relative influence of these processes on terrestrial carbon budgets generally increasing at higher latitudes and elevations. The timing and duration of soil freeze/thaw state are closely linked to vegetation phenology, and growing season dynamics in northern temperate, sub-alpine, boreal and arctic biomes. Variability in these environmental variables also has been shown to have dramatic impacts on spatial patterns, seasonal to inter-annual variability and long-term trends in terrestrial carbon budgets and surface-atmosphere trace gas exchange primarily through biophysical controls on both photosynthesis and respiration. These processes are strongly influenced by land cover and soil properties, as well as the timing and condition of seasonal snow cover. Based on this background, we will integrate remote sensing data sets, ground-based measurements, and numerical modeling to quantify the effects of soil temperature, soil freeze-thaw dynamics, and snow cover on seasonal to inter-annual variability in the North American terrestrial carbon cycle. Our overall goal is to understand the role of freeze-thaw processes in determining seasonal and inter-annual variability in terrestrial biomass, photosynthesis, respiration, and net CO2 fluxes over continental North America. Using remote sensing products, in situ observations, and a soil thermodynamic model, we will estimate soil temperatures and snow cover over North America at 25-km resolution for North America from 1981-2003 (23 years). We will feed these estimated soil temperatures and snow cover, along with additional remote sensing data, into an ecosystem model to estimate biomass and net carbon fluxes. Both models will use the North American Regional Reanalysis, so the resulting estimates of soil thermodynamic properties, biomass, and carbon fluxes will be optimally consistent with each other and with actual weather conditions in North America. We will statistically analyze these optimal carbon fluxes to understand the environmental drivers and biophysical responses regulating the spatial patterns and temporal variability in the North American terrestrial carbon cycle. Using standard Monte Carlo techniques, we will quantify uncertainty in our estimated carbon fluxes. Lastly, we will perturb our input data to assess the sensitivity of our estimated fluxes to long-term climate change.

Integrating Land, Coastal Margins, and Oceans

G.1: A large knowledge gap in the NACP: The role of intertidal marshes in the transfer of CO_2 between the atmosphere and the ocean

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Early recognition of coastal intertidal marshes as highly productive ecosystems led to the hypothesis that marshes contribute significant amounts of organic carbon to estuaries and the coastal ocean. This outwelling hypothesis was later challenged, at first because there were insufficient supporting data, and later because new data and more detailed models of estuaries did not reveal large fluxes of organic matter from marshes. The validity of the outwelling hypothesis is just one component of the larger issue of the trophic status of estuaries, and particularly the importance of estuarine heterotrophy on a global basis.

In recent years, my group has studied the coastal metabolic balance issue in the context of air-sea CO_2 flux with the goals of finding the source materials and mechanisms that support CO_2 evasion in coastal waters. Estuarine and nearshore waters in Georgia are nearly always highly supersaturated with respect to atmospheric CO_2. Some large flux values were estimated with perhaps great uncertainty for two main reasons. First, estuary-marsh systems are highly heterogeneous and of great dynamics, thus making water-air flux measurements less representative and meaningful. The second difficulty comes from not knowing precisely the areas of various subsystems (open water, marsh-plants, mud flat etc) thus making up-scaling to regional or global fluxes highly uncertain. Because of the extremely strong CO_2 signals and large uncertainties in the areas, special attention is called to address this knowledge gap in the boundary between the land and the coastal oceans within the context of the NACP.

G.2: Carbon fluxes, transformations, and transports along the North American margin: A multi-scale modeling assessment.

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The coastal ocean is characterized by intense biological productivity and highly energetic circulations, which mediate the interaction between terrestrial and oceanic carbon cycles. Key influences on coastal oceanic carbon cycling include strong eddy activity, massive nutrient fluxes, extreme oxygen variations, and a range of terrestrial and sedimentary exchanges. Most of these processes are however, highly undersampled by observations and, at best, poorly represented by global carbon cycle models, making the understanding and estimation of coastal ocean carbon fluxes and transformations a formidable challenge. We present a combination of modeling and observational approaches to constrain the net carbon fluxes to and from the coastal ocean of the US west coast, and to investigate its influence on the broader Pacific basin. Observations from three mooring time series stations, together with results from an ecosystem model embedded in an eddy-resolving regional circulation model (ROMS), suggest that the air-sea CO_2 flux of the U.S. west coast may be nearly balanced between regions of net outgassing (e.g. the Southern California Bight) and net ocean uptake (e.g. the Oregon margin). Within the water column however, the presence of mesoscale eddies promotes an imbalance between the fixation and respiration of CO_2, resulting in an excess of photosynthesis in the coastal zone and a net flux of organic C to the open ocean. Simulations with a coarse resolution model further indicate that the coastal ocean may play an important role in generating biogeochemical variability in the open North Pacific. Taken together, our results highlight the importance of eddy-scale processes and regional differences in the carbon cycle of the coastal zone of the U.S. Pacific coast, and potentially of the broader ocean basin.

G.3: Carbon Fluxes and Transformations across Estuaries - a Combined Physical and Geochemical Approach

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Estuaries are critical interfaces between terrestrial and marine environments. The processes responsible for the transfer and transformation of carbon in estuarine systems are extremely dynamic and especially sensitive to anthropogenic activities and climate change. New approaches are exploring the interconnections between physical forcings (e.g., waves and currents) and geological (e.g., sediment transport and deposition), chemical (e.g., carbon turnover and burial), and biological processes (e.g., primary and secondary production, species compositions) in these environments. In this study we investigate the fluxes and transformation of particulate organic matter along a section of a temperate estuary (Winyah Bay, South Carolina, USA) that brackets the estuarine turbidity maximum. We apply several geochemical, optical and acoustic techniques to measure net fluxes of water, salt, total suspended sediments, particulate organic carbon and particulate nitrogen over full tidal cycles during several seasonally distinct periods of contrasting river discharge and tidal conditions. We combine these data with compositional information of the particles in suspension to assess the effects of physical forcings on the fate of particulate organic matter in this estuary. The combined physical and geochemical approach and the resulting data are discussed as an example of how to conduct future studies designed to quantify carbon fluxes across this critical interface in coastal margins.

G.4: Integrated Study of the Carbon Budget of the Continental Shelf of the Mid-Atlantic and South Atlantic Bights

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The U.S. Eastern Continental Shelf Carbon Budget (U.S. ECoS) Program, funded as part of the NASA Interdisciplinary Science Program, has as an overall goal the development of carbon budgets for the Mid-Atlantic Bight (MAB) and South Atlantic Bight (SAB) along the eastern U.S. coast. The U.S. ECoS program is structured around five themes: 1) development and implementation of circulation, biogeochemistry, and carbon cycling models for continental shelf waters of the U.S. east coast, 2) analyses of historical in situ

measurements and satellite-derived data, 3) acquiring limited field measurements designed to provide inputs to the biogeochemistry and carbon cycling models, 4) development and implementation of data assimilative biogeochemical and carbon cycling models, and 5) interfacing the circulation, biogeochemistry and carbon cycling models with climate models. The U.S. ECoS program has implemented a coupled circulation-biogeochemical-carbon model for the MAB and SAB regions. The carbon model includes land and ocean carbon sources and is linked to a model of nitrogen cycling. Simulation results underlie development of a carbon budget for the MAB and SAB continental shelf regions. Concurrent analyses of historical satellite-derived ocean color data sets provide insight into processes that underlie patterns of variability of chlorophyll, primary production, particulate organic carbon, and dissolved organic carbon for MAB and SAB continental shelf waters. These project results are relevant to the goals of the North American Carbon Program.

Regional Analyses

H.1: The combined influence of historical livestock grazing and pinyon-juniper woodland thickening on ecosytem C stocks in southern Utah

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Pinyon-juniper woodlands are expanding into a wide range of ecosystems across the western United States. Recent syntheses suggest that woody plant encroachment may contribute significantly to a North American carbon sink but these estimates are variable and highly uncertain. To better understand the role of woody expansion and historical landuse on ecosystem C stocks, we compared above and belowground C stocks on a remote mesa with very little historical livestock grazing (No Man's Mesa) to a site that has been grazed by livestock since the mid-1800s (Deer Springs Point). We mapped aboveground biomass across these study sites using a combination of AVIRIS airborne imaging spectroscopy and field-based allometric data. Aboveground biomass was similar across these sites and was in the range of 1.5 kg C/m^2. Coupled with the stand age structure data, which suggests that pinyon recruitment rates are similar across the two sites, we have concluded that historical livestock grazing in these sites had little effect on aboveground C stocks. Historical tree expansion did lead to a large increase in both soil and aboveground carbon storage in this region and thus supports the notion of a regional C sink due to woody encroachment. However, most soil organic matter (SOM) is found in unstabilized pools of soil carbon with decadal residence times. These pools and aboveground pools of vegetation C both are highly prone to disturbance and loss during events such as fire, suggesting that this sink may be relatively short term and closely tied to decisions regarding wildland fire management.

H.2: Carbon Dioxide and $\delta^{13}C$ of CO_2 at Multiple Spatial Scales Over the Rocky Mountains

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Recent studies suggest that 25 to 50 percent of the U.S. carbon sink can be attributed to montane ecosystems of the western U.S. Isotopes of CO_2 provide insight into ecosystem carbon cycling, plant physiological processes, and atmospheric boundary-layer dynamics, and are useful in integration of processes over multiple scales. We examined biosphere-atmosphere exchange of CO_2 and its stable isotopes in and above the Rocky Mountains in Utah and Colorado. Measurements were made at a total of 7 sites representing several different spatial scales (forest and region, including vertical profiles). These include 3 sites from the NOAA/CCGG Cooperative Air Sampling Network, 3 sites from the RACCOON network, and an AmeriFlux forest site at Niwot Ridge, Colorado. Observed CO_2 and $\delta^{13}C$ showed seasonal variation (> 10 ppm and > 0.5 permil) and strong local variation at all sites (> 100 ppm and > 5 permil at the forest site). The forest exerted a strong respiratory influence on the overlying air during the fall and winter. Measurements 10m above the top of the forest canopy in winter were always higher in CO_2 (± 3 ppm) and more negative in $\delta^{13}C$ of CO_2 (± 0.3 permil) than those from the nearby (< 3km) NOAA site (Niwot Ridge). Substantial synoptic variation in CO_2 and $\delta^{13}C$ was observed at all sites, sometimes with simultaneous changes at all sites, sometimes not. The diurnal and seasonal patterns of CO_2 and $\delta^{13}C$ at all sites will be used to assess the local variability of the long-term CO_2 and $\delta^{13}C$ record at Niwot Ridge.

H.3: The ORCA West Coast Regional Project: Ground measurements made across key vegetation gradients

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The ORCA West Coast Regional Project uses a physiological process model parameterized with remote imagery to make temporally and spatially explicit estimates of carbon stocks and fluxes across Oregon and northern California. In addition to assessing output against ground measurements of biomass (from forest inventory) and carbon dioxide flux

balance (from eddy covariance towers) model output can be assessed against detailed ground measurements of carbon stocks and fluxes across key disturbance gradients that are deemed ecologically significant, management relevant, and that target suspected weaknesses in remote detection and model structure. Efforts are currently focused on four such gradients including: 1) clear-cut harvest Chronosequences in the Cascades and Coast Range, where measurements reveal that only the youngest stands exhibit negative NEP and that the age at which NEP becomes positive depends on climate and resource availability; 2) a wildfire severity gradient in Siskiyou Mountains, where measurements reveal that pyrogenic emissions are dependent on severity and that reductions in post-fire NEP are driven first by reductions in GPP not through increases in Rh; 3) a forest thinning gradient in the Sierra Nevada, where measurements suggest that belowground carbon dynamics are less sensitive to thinning than aboveground carbon dynamics and that increases in shrub productivity may quickly compensate for reductions in overstory LAI; 4) woody encroachment in the Steens Mountains, where we suspect juniper encroachment to increase NPP, and possibly GPP, but not necessarily NEP.

H.4: Evaluation of ecosystem carbon dynamics in North America using hourly to decadal data on local to regional scales

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There are major uncertainties in the causes and magnitudes of ecosystem CO2 fluxes, and hence ecosystem carbon storage, in North America. Because of the complexity, and varied spatiotemporal scales, of the key processes, detailed process-based models are needed to understand and predict carbon fluxes and storage. It is crucial that these models are constrained properly, calling for an integrated modeling-data approach utilizing data at a wide variety of scales. The increasing availability of such data for North America could allow fundamental improvements in vegetation models, reducing uncertainties in estimates of current and future carbon fluxes and storage.

We combine two different data sources (eddy flux, forest inventories) to estimate biophysical parameters for the state-of-the-art dynamic vegetation model LM3V. This model has been jointly developed at Princeton and NOAA/GFDL and has been successfully coupled to the GFDL atmospheric and climate models. Eddy flux data provide information on terrestrial carbon fluxes at short (hourly to seasonal) time-scales, whereas the USDA forest inventories measure land carbon over decades to a century, including physiological and ecological changes within ecosystems, which is needed to accurately simulate ecosystem carbon dynamics in the context of climate change. These data thus mutually constrain model parameters, accounting correctly for the varied spatiotemporal scales of the processes. Following data availability, we focus on the East of the United States.

H.5: Regional carbon fluxes by simultaneous assimilation of multiple flux towers in a simple ecosystem model

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Assimilation of eddy covariance flux data into ecosystem models is a promising avenue for constraining model parameters, quantifying regional flux and evaluating CO2 flux interannual variability. Typically, this optimization has been done with a single site and extrapolation to larger regions is suspect. The ability to capture interannual variability of CO2 flux by these methods has been limited in success. Here we applied a well tested parameter optimization method and simple ecosystem model to allow for assimilation of multiple co-located eddy covariance flux towers simultaneously. In this spatial assimilation, the model parameter set has both global parameters and site specific parameters that can be tuned based on eddy covariance CO2 and H2O flux observations. Using regional landcover information, the multiply constrained model is hypothesized to be better able to model regional flux on hourly to interannual timescales, especially in heterogeneous landscapes.

We applied the Sipnet ecosystem model to the upper Midwest and constrained the model with flux data collected by the Chequamegon Ecosytem-Atmosphere Study (ChEAS) cooperative. The region is a patchy mosaic of wetlands and uplands. Wetland and upland flux towers were used to constrain a subset of model parameters with the Markov Chain Monte Carlo method. Others parameters were set to observed or inferred values. Model results reveal the successes and limitations of this approach and provide insight into its potential for quantifying regional flux, predicting future change in ecosystem flux and estimating impacts of climate change - all central activities of the North American Carbon Program.

H.6: Mechanisms Controlling Annual, Interannual, and Decadal Changes in California's Carbon Budget

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We are using remote sensing-based measurements of land-surface properties, in-situ measurements of land-atmosphere exchange, mechanistic models of biogeochemistry and atmospheric transport, and information on fossil fuel use, agricultural yield, land use, and biomass to better understand California's Carbon budget. Findings to date include: (1) California's NPP in the early 2000s (190 x 10^12 gC y-1) was roughly double its fossil fuel emission (95 x 10^12 gC y-1). Since ecosystem carbon storage is typically less than half NPP, California's net C budget was dominated by fossil fuel emissions. (2) Fluctuations in natural ecosystem NEP caused by climate variability (18 x 10^12 gC y-1) were the dominant cause of interannual carbon cycle variability. Fluctuations in fossil fuel consumption caused by the business cycle (8 x 10^12 gC y-1), fluctuations associated with wildland fire (3 x 10^12 gC y-1), and fluctuations associated with agriculture (1 x 10^12 gC y-1) were smaller. (3) Approximately 50% of California's fossil fuel emissions are advected to the south or west; only 50% of California's fossil fuel emissions are transported east, creating a challenge for efforts to use longitudinal CO2 gradients to constrain North America's carbon budget. (4) Alternative spectral indices based on visible greenness (VARI or VIG) or that include information on short-wave IR absorption (NDWI, NDII7 or RSR) were more tightly correlated with LAI, live fuel moisture, and whole ecosystem CO2 flux than more commonly used near-IR-based indices (NDVI, EVI). (5) Unmanaged forests, especially in the Sierra Nevada Mountains, have lost carbon over the last 70 years as a result of the selective mortality of large trees. This mortality was likely caused by episodic insect outbreaks, which may have been exacerbated by stand thickening associated with fire suppression.

H.7: A multiple constraints model-data assimilation scheme to combine MODIS thermal and AMSR-E microwave image products for estimation of land surface variables and fluxes in tropical savannas

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This poster demonstrates the application of a multiple constraints model-data assimilation (MCMDA) scheme to the combination of AMSR-E soil moisture content (SMC) and MODIS land surface temperature (LST) in a coupled biophysical model for the tropical savannas of northern Australia. These methods are demonstrated with a view to their extension to other savanna regions and global biomes. The results show that, on their own, AMSR-E SMC data were poor constraints to the model. Incorporating LST data via the MCMDA framework ameliorated deficiencies in the SMC data and resulted in enhanced characterization of land surface soil moisture and energy balance. On average the model predicted wetter SMC values (~0.04 g cm $^{-3}$) and cooler LST's (~1.7 K) than the satellite image products.
In the MCMDA scheme, an objective function measures the mismatch between model-predicted and satellite-observed SMC and LST. Numerical search routines were employed to give an optimum choice of the tuning parameter g_{max}—the canopy-averaged maximum stomatal conductance—that minimized the objective function. In terms of RMSE, an optimal fit to both image product datasets resulted in an increase by 84% for predicted SMC and a 0.06% increase for LST relative to the fit to each dataset separately.
Also comparisons of model estimates of canopy stomatal conductance, g_c, and latent heat flux, λE, with those obtained from a MODIS evapotranspiration product revealed good agreement, with RMSE for g_c = 0.5 mm s^{-1} and for λE = 18 W m^{-2}.
The MCMDA scheme's capability for handling multiple incommensurate datasets is of key importance for improved forecasting of land-air exchanges of water, energy and carbon in savanna systems around the world including North, Central and South America.

H.8: Quantifying surface fractional cover using remote sensing for improving land surface schemes of water and carbon fluxes in tropical savannas

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Quantification of the surface fractional cover is needed as a lower boundary condition to underpin accurate carbon, water and energy balance modeling in all land systems including those of North and South America. Our work in Australian tropical savannas seeks to integrate spectral data and vegetation indices from MODIS and Hyperion, with spectral libraries and fractional cover surveys from field campaigns, and high resolution "snapshots" of fine scale structure to define fractional cover of trees, green and dead grass, and bare ground.

Spatial resolution and spectral band location in the short wave infrared, particularly above 2000 nm limits sensitivity of MODIS spectral data to variation in dead and bare fractions. However, recent research has shown that spectral angular indexes from 7 band MODIS data show promise in improving fractional cover retrievals. We are seeking to develop a processing sequence that maximizes the information on fractional cover that can be extracted from sub-optimal combination of data from temporal, spectral and spatial

domains.
Up to this point, we have found that:
1. Time series of MODIS NDVI or EVI can be decomposed to provide information on the proportions of perennial and annual vegetation.
2. Spectral signatures from Hyperion can be convolved to MODIS bands and used in a combination of spectral unmixing and time series analysis to infer some information about fractional cover.
3. MODIS 16-day composite reflectance (MOD43) can detect the effects of grazing around livestock water points in those vegetation types with low tree cover.
4. Angular indexes from MODIS spectra pivoting on the SWIR1 band offer significant potential for improving fractional cover retrieval.

In January, we will report results from analysis of MOD43spectral and index time series in relation to field and Hyperion spectra convolved to MODIS bands, and in relation to high resolution imagery and ground data defining fractional cover. A processing framework to maximize fractional cover information for these savannas will be outlined an its potential extension to North, Central and South American land systems will be discussed.

H.9: Markov chain Monte Carlo: Practical Aspects of its Application to Terrestrial C-Cycle Model-Data Assimilation

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There is an ever increasing realization that, for most environmental modeling problems, greater insight is gained from the utilization of multiple “orthogonal” datasets than from any single dataset. To this end, there remains the question of how best to combine these different and disparate sources of data with physical models.
Multiple constraints model-data assimilation (MCMDA) provides a framework within which data and models are combined to estimate land surface variables and parameters. A key element to MCMDA is the numerical search algorithm used to obtain the optimal set of model parameters that minimizes a cost function comprised of observational data and model predictions.

In this poster we explore some of the practicalities and challenges faced when Markov chain Monte Carlo (MCMC) is used as a global search algorithm to estimate the parameters and initial conditions of a simple C-cycle biophysical model. Specifically, two versions of the Metropolis-Hastings (MH) algorithm are applied to synthetic datasets of remotely-sensed observations (including land surface temperature and NDVI), flux tower measurements and in situ data.

H.10: Beyond Potential Vegetation: Characterizing Forest Structure for Assessments of Carbon Cycling and Biodiversity

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The overall science goal of this project is to link lidar remote sensing of forest structure with field studies and ecosystem modeling across a range of environmental gradients to improve land surface carbon predictions, and to explore the effects of this structure on species richness and distributions. The activities of this research fall into three categories: (1) the production of a time series of forest structure from lidar and other remote sensing data; (2) the modeling of carbon stocks and fluxes using a height-structured ecosystem model (ED) initialized with lidar data; and (3) application of the derived and modeled products for assessments carbon and biodiversity. The bases for these activities are airborne lidar LVIS data sets acquired in 1998-1999, and again in 2003-2005, at a set of study sites including La Selva Biological Station (Costa Rica), the Hubbard Brook, Harvard Forest, and Coweeta LTER sites, Bartlett, Duke, and Patuxent forests, as well as extensive flying in the Sierra National Forest in California.

H.11: Coupling an individual-based forest gap model with remote sensing: Patterns and variations in net primary production.

Anthony Wayne King, Oak Ridge National Laboratory, kingaw@ornl.gov (Presenting)

Forest recovery following both natural and anthropogenic disturbance involves changes in stand structure and demography, successional changes in species composition, and changes in carbon stocks. These changes have important implications for carbon cycling in North America and are major determinants of the size and future of the North American terrestrial carbon sink. While the best understanding and theory of forest recovery are captured in individual-based "gap" models of forest succession, these models need to be linked with the spatially extensive, regional data provided by space-based remote sensing. I am linking an existing individual-based forest succession model (LINKAGES v2.2) with remotely sensed data from different sensors and platforms, but primarily with data from the MODIS sensor on the Terra and Aqua spacecraft. Here I describe the coupling of the forest succession model with remote sensing data, focusing on net primary production (NPP). I compare the uncoupled model’s simulation of NPP for the forests of eastern North America with the MODIS NPP product for the region, and I describe the implications for modeled net ecosystem exchange and carbon storage when constrained by MODIS NPP. I examine the influence of climate, soil and stand age on model variations in NPP and compare with patterns of MODIS NPP variation with climate and soil in an exercise evaluating the inference of stand age from MODIS NPP. I also examine variations in NPP associated with species composition and succession within the broad MODIS plant functional type (PFT) of Deciduous Broadleaf Forest.

H.12: The ORCA West Coast Regional Project - Use of Top-Down Modeling in a Regional Carbon Budget Approach to Estimate Gross Carbon Fluxes for Oregon-California

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The ORCA project aims at determining the regional carbon balance of Oregon and northern California (see also Law et al., this meeting), with a special focus on the effect of disturbance history and climate variability on Carbon sources and sinks. ORCA provides a regional test of the overall NACP strategy by demonstrating bottom-up and model-data fusion approaches to derive carbon balances of a larger area.

The top-down modeling component of ORCA focuses on coupling simple process models for GPP, RA and RH with atmospheric transport modeling to interpret measured CO2 concentration data. This approach builds on high-resolution remote sensing products (e.g. Landsat, MODIS) as well as spatial meteorological datasets (EDAS, DayMet) to drive the models. We employ STILT (Stochastic Time-Inverted Lagrangian Transport) footprints to determine the relative influence of each part of the region surrounding the observation site on the measured concentrations, and to identify the composition of landcover types within this area. The information on the contribution of fluxes emitted by the different landcover types to the CO2 measurements is subsequently used to optimize base rates in the parameterization of the process models.

We present a proof-of-concept of the ORCA top-down modeling approach by comparing modeled to measured CO2 concentration data. This comparison also addresses the uncertainties introduced by different components of this approach. To demonstrate the effect of the improved process model parameterization, the results will be compared to the regional fluxes derived by the ORCA bottom-up component.

H.13: The ORCA West Coast Regional Project

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The project objectives are to reduce uncertainty in understanding C sources and sinks, and to determine the effects of disturbance and variation in climate on the regional carbon balance in the western U.S. over the past 30 years. We combine a spatially nested hierarchy of observations with bottom-up and top-down modeling to estimate carbon stocks and fluxes over the region (Oregon and Northern California). Field observations are used for model parameters (e.g. foliar nitrogen and SLA from 200 extensive plots), for look-up tables (e.g. proportions of different biomass pools burned off in wildfires), and for development of remote sensing algorithms (e.g. for mapping LAI). Forest inventory data are used to evaluate model outputs (e.g. wood mass), and tower flux and carbon dioxide concentration data are used for parameter optimization in model-data fusion. We have begun application of a diagnostic carbon flux model (driven with MODIS data) which is integrated with the STILT model for atmosphereic transport. Our bottom-up scaling has been used to generate a carbon budget for Oregon. Landsat resolution (30m) remote sensing provided the basis for mapping land cover and disturbance history, identifying major fire and logging events over 30 years. For net ecosystem production (NEP), ecoregion-specific parameters and distributed meteorology were used to drive Biome-BGC. For net biome production (NBP), we used county harvest statistics for logging removals, USDA statistics for crop removals, and remote sensing based estimates of area burned and our mapped biomass estimates for fire emissions. Evaluation of our modeled carbon pools and flux was by reference to flux tower data, extensive field plots, and forest inventory data. All of the predominately forested ecoregions were significant NEP sinks. Agricultural ecoregions were also NEP sinks because decomposition of crop residues did not balance NPP. Crop and forest harvest removals amounted to about half of the NEP, so state-wide NBP remained positive most years.

H.14: Simulated changes in soil organic carbon stock with different tillage practices in the northwest Great Plains

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We simulated effects of tillage management on the dynamics of soil organic carbon (SOC) in the northwest Great Plains, using the General Ensemble Biogeochemical Modeling System (GEMS) coupled with a block sampling protocol. We set three tillage management scenarios: conventional tillage (CT), no-till (NT), and actual tillage management which in 1998 consisted of CT (23.5%), NT (38.4%), and reduced tillage (38.1%). The model simulations indicate that there was a large carbon (C) source on all croplands between 1972 and 2001 with 253 kg C/ha/yr released to the atmosphere under CT and 199 kg C/ha/yr under NT. The change in total SOC stock was predominantly a result of the change in the

slow carbon pool at the study's time scale. Results suggest that the response of SOC to tillage management depends on the baseline SOC level: soils having higher SOC levels tend to lose more carbon under CT but have a higher potential to reduce carbon emissions with NT management.

H.15: An Analysis of Regional Carbon Stocks Estimates Using Airborne and Spaceborne Lidar in Quebec

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We are evaluating the potential of lidar data from the GLAS-ICESAT sensor to measure aboveground carbon stocks at the regional level in Quebec. In August 2005, we conducted flights using the Portable Airborne Lidar over (1) a range of ground plots and (2) along five, several-thousand-km long, north-south transects of GLAS data collected in October 2003 (Collection 2a). This information was integrated together with Landsat land cover and SRTM topographic data. The strongest relationships between PALS-derived biomass and different measures of vegetation height from GLAS (n~8000) varied between ecozones and were strongest in the northern temperate zone comprised largely of deciduous and mixed forest. The relationship between PALS biomass and GLAS height was stronger for pulses that had homogenous land cover. The equations that we developed allow us to use GLAS data to estimate of carbon stocks for the entire landmass of Quebec that lies south of the treeline.

H.16: Regional scale land-atmosphere CO_2 exchange: Assimilation of surface and airborne network data within a receptor-oriented modeling framework

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We quantify and characterize terrestrial CO_2 exchange at the regional (~10^4 km^2) scale in the Northeast U. S. and southern Quebec during summer 2004 through an end-to-end model data fusion study. Our dataset is both spatially and temporally representative of the region, consisting of continuous surface concentration data from the NOAA GMD ESRL Argyle Tall Tower and four other concentration monitoring locations throughout the region, and 200 hours of airborne concentration data from the COBRA-Maine airborne campaign. Surface fluxes are characterized by optimizing the parameters of the Vegetation Photosynthesis and Respiration Model (VPRM), a simple biosphere model that integrates satellite data, AmeriFlux eddy covariance measurements, and meteorological fields. The surface flux model is coupled to a Lagrangian atmospheric adjoint model, the Stochastic Time-Inverted Lagrangian Transport Model (STILT), that links point observations to upwind sources with high spatio-temporal resolution. Forward model calculations represent remarkably realistic *a priori* conditions for Bayesian inversion of the atmospheric concentration data. There is a high amount of redundancy due to spatial and temporal correlation of these observations, which drastically reduces the degrees of freedom in the optimization, emphasizing the need for large amounts of diverse and independent data to constrain even a limited number of parameters. The spatial coverage of airborne data proved strongly complementary with the temporal coverage provided continuous tower observations. The atmospheric concentration dataset provides significant constraint for the model and optimization leads to surface flux parameters with greatly reduced uncertainty. However, the ability to model observed atmospheric CO_2 is still limited by errors in the model unrelated to the surface flux parameters: especially atmospheric transport, boundary conditions for the region, and environmental drivers for surface fluxes (e.g. radiation). These errors can be systematic and biased, and since they are unrelated to the surface flux model may lead to biased flux parameters and/or underestimates of parameter uncertainty.

H.17: Climate change, carbon storage and function of Taxodium distichum swamps

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Predictions can be made about the potential effects of climate change on wide-ranging ecosystems based on shifts in their function across their geographical range. Taxodium distichum is a forested wetland type that spans the southeastern part of North America, and a good candidate for climate analysis. Study sites were established in similar swamps at each of 7 latitudes in the Mississippi River Alluvial Valley from Illinois to Louisiana, to make comparisons of carbon storage, production, and regeneration dynamics across the climate gradient. An additional set of study sites may be added in Texas to capture western populations subjected to drier conditions. Swamp leaf production, root production and tree height were highest in mid-range, and lower in the northern and southern parts of the range, i.e., a curvilinear pattern. Seed bank densities are generally related to temperature and precipitation levels, so that regeneration patterns may shift with climate change. A climate change model suggests that climate warming and drying could decrease the range of

swamps in the western and southern part of the range. Knowledge of the response of baldcypress swamps to differences in climate across the latitudinal range can give evidence of the response of these species to climate change, and thus help lead to models that more accurately predict the distribution of these wetlands in the future.

H.18: Integrated Regional Land System Modeling: Integrative approaches to understand C dynamics in complex landscapes

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The pressure on earth resources is increasing due to human related activities caused by continued industrial growth, extraction from oceans for food and other resources, land conversion for agricultural and wood extraction, and use of water resources for urban and agricultural production. Earth system science has developed immensely during the past decade, especially in the area of understanding the role of the biosphere in controlling the water, carbon, nitrogen, and vegetation dynamics. The availability of recent developments in observational and analytical technologies related to isotopic analyses, tower based instrumentation and satellite interpretations enhances our ability for investigating teleconnections of the earth system. The development of the computing infrastructure for investigations of anthropogenic effects on land atmospheric interactions have greatly enhanced our ability to further our basic science understanding, enable environmental assessment of critical earth system issues, and provide current scientific input to education/outreach related to environmental conditions. Research efforts are now ongoing to address how to integrate modeling and research efforts to advance our ability to understand how changes in land use and natural disturbances are affecting the Earth System. Recent analysis of combined land fluxes, aircraft observations, satellite observations have been integrated with ecosystem level modeling into a data-model fusion framework to evaluate land use and disturbance changes on land-atmosphere interactions over mountainous terrain over the Western United States.

H.19: Effects of Future Changes in Climate and Atmospheric CO2 Concentrations on Northeastern U.S. Forest Ecosystems

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We used the PnET-CN ecosystem model to evaluate the effects of predicted changes in climate and atmospheric CO2 on carbon, water and nitrogen balances at five research sites in the northeastern United States. High resolution climate change predictions were generated using a statistical downscaling approach applied with two general circulation models (HadCM3 and PCM) and two CO2 scenarios (IPCC A1 and B1). A series of ecosystem model experiments was then conducted to examine the individual and combined effects of temperature, precipitation, CO2 and various assumptions regarding the physiological response of forests to these changes.

Results indicate a wide range of predicted growth rates, ranging from large increases across deciduous sites under most future conditions to growth declines in northern spruce forests under the warmest climate scenarios and in some deciduous forests when CO2 fertilization effects were absent. Both climate and CO2 contributed to predicted changes, but their relative importance shifted from CO2 - dominated to climate - dominated from the first to second half of the 21st century. Interestingly, the effects of climate change on NPP were much smaller when CO2 was held constant, whereas CO2 alone had an important effect with and without climate change. Interactions between the two involve tradeoffs between growing season length, mid-summer drought, water use efficiency and temperature stress. Predicted runoff ranged from no change to a slight decrease, depending on future precipitation and whether or not stomatal conductance was allowed to respond to rising CO2. Nitrate leaching exhibited highly variable responses, with N leaching being highest under conditions that imposed plant stress with no physiological effects of CO2.

H.20: Modeling Complex Effects of Multiple Environmental Stresses on Carbon Dynamics of Mid-Atlantic Temperate Forests

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We used our GIS variant of the PnET-CN model to investigate changes of forest carbon stocks and fluxes in Mid-Atlantic temperate forests over the last century (1900-2000). Forests in this region are affected by multiple environmental changes including climate, atmospheric CO2 concentration, N deposition and tropospheric ozone, and extensive land disturbances. Our objectives are to gain mechanistic understanding of the complex interactive effects of changing environmental factors on forest carbon dynamics, and to partition the forest carbon responses to different causes. Our results indicate that, for the whole forest area in the Mid-Atlantic, net primary productivity (NPP) increased by 25% over the

last century due to chronic changes in climate and atmospheric chemistry. Among these factors, change in climate increased NPP by 4%; interannual climate variability caused 7% lower NPP; and changes in atmospheric chemistry had the dominant impact of increasing NPP by 34%, while 5% of this impact was further reduced by the interaction with interannual climate variability. With consideration of land disturbances, NPP may end up increasing more due to a greater response to N deposition which may compensate for N loss in disturbed soil pools. Annual net ecosystem productivity (NEP) fluctuated annually and was affected primarily by climate variability. This research shows that changes in atmospheric chemistry could be important driving variables that affect net carbon change in regions where air pollution is a significant factor.

H.21: Terrestrial Carbon Cycle Parameter Estimation and Model Performance Improved by Removing Noise From Satellite Time Series Data

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Changes in leaf area that occur over time periods of days have large effects on terrestrial ecosystem carbon cycle model estimates of regional carbon exchange. Currently available MODIS LAI observations contain significant amounts of gaps and noise due to less than optimal atmospheric conditions for making measurements. Carbon cycle model parameter estimation using eddy covariance data using the LoTEC model at several AmeriFlux sites show sensitivity to this noise that affects optimal parameter estimation. In particular, parameters for the amount of growth respiration are affected. Spatially gap-filled smoothed LAI data were processed with two steps. First, TIMESAT Asymmetric Gauss (AG) approach was used to generate smoothed LAI data and phenology parameters from standard MODIS LAI product (8-day composite in 1-km resolution). Second, spatial gaps were filled by adjusting temporal curve of high quality neighbor pixel of same land cover type from MODIS land cover products using high quality LAI values from current pixel. Use of this spatially gap-filled smoothed LAI greatly improved LoTEC carbon cycle model representation of carbon NEE at selected AmeriFlux sites.

H.22: Where do Fossil Fuel Carbon Dioxide Emissions from the Western U.S. Go? An Analysis Based on an Atmospheric Model Validated Using Radiocarbon Observations (A Component of NACP-W)

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We describe a combined measurement and modeling approach to assess the fate of fossil fuel CO_2 emissions released within California. In our analysis, we compared the ^{14}C content of annual C_3 grasses with spatially and temporally resolved fossil fuel CO_2 concentration estimates obtained using a coupled modeling framework that included MM5 (atmospheric model), ISOLSM (a land-surface model), and emissions inventories. Annual grasses sampled at the end of the growing season represent a weighted (with photosynthetic uptake) growing season atmospheric CO_2 sample, and their ^{14}C content can be used to infer the fraction of assimilated carbon associated with fossil fuel. We sampled grasses at over 100 Californian sites; measured ^{14}C content ranged from ~-10 to ~60 permil in densely and sparsely populated areas, respectively. Patterns of measured and predicted grass ^{14}C content were consistent, indicating that our modeling approach worked well. We applied the coupled model to assess fossil fuel CO_2 transport out of the region. Accumulated over the year, about half of California's fossil fuel CO_2 emissions exit to the south within the atmospheric boundary layer (ABL) while most of the remaining exits to the east in a lofted plume. Substantial seasonal variability exists in these transport patterns. Therefore, continental 'top down' inversions of North American sources and sinks need to characterize north to south flow components, transport within the ABL, and exchange between the ABL and free troposphere.

H.23: Cross-site Evaluation of Hyperspectral and LIDAR measures of forest species, physiology and structure

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LIDAR and hyperspectral data have the potential of improving estimates of carbon stocks and fluxes through structural/height measures and detailed maps of forest species and physiology. While strong relationships have been observed between LIDAR-derived height measures and above ground biomass, it is not clear whether these relationships are global or site specific or how they vary depending upon management, disturbance and climate. Furthermore, it is unclear the extent to which hyperspectral data complement LIDAR by providing measures of health, physiology and species. To address these questions, we are evaluating LIDAR and hyperspectral data from six diverse, well characterized

sites including tropical rainforest (La Selva), western coniferous forest (Wind River and Sierra Nevada), continental coniferous forest (Yellowstone) and east-coast broadleaf deciduous forest (Harvard Forest, SERC).

To facilitate comparison of diverse LIDAR and hyperspectral data sets, we are applying a common set of analytical tools to each data type. LIDAR metrics we evaluate include several height measures (quantiles, mean, median and maximum heights), canopy complexity measures (rugosity, rumple index) and synthetic waveforms derived from small-footprint lidar at plot scales. Hyperspectral measures include species-level maps developed using Multiple Endmember Spectral Mixture Analysis, and hyperspectral indices sensitive to canopy water, chlorophyll, leaf area and light use efficiency. We report on analysis for four sites, Yellowstone, Wind River, SERC and La Selva, focusing on lidar-derived estimates of biomass and tree height across sites and initial hyperspectral mapping of forest species. We also compare lidar-derived height and biomass to hyperspectral-derived physiological measures between sites, species and age classes.

H.24: Distribution of Aboveground Carbon Stock in North American Forests

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There is a general agreement that the terrestrial ecosystems in Northern Hemisphere are a significant sink of atmospheric carbon. However, the uncertainties in geographic distribution of this sink and its spatial and temporal variations due to changes in human and climate forcing are substantial. Consistent and spatially refined distribution of carbon stock and its changes through time provide measurement-based constraints on estimating both the carbon uptake of ecosystems and their sustainability through time. This paper summarizes the methodology and the results from a NASA sponsored study to estimate the carbon stock in North American forests at the turn of 21th century, circa 2000. The goal of the study was to integrate remote sensing data from MODIS, SRTM, JERS, and Radarsat and forest inventory plots from US and Canadian forest service to estimate the spatial distribution of above ground forest biomass in North America. We report the results of the study in two parts. The first part focuses on the methodology and provides the distribution of carbon stock in forests of northeast and southeast regions of the US. The second part of the paper shows how the quality of the data and the errors associated with the methodology create uncertainties in measuring the carbon stock and evaluating the sink and source terms on the regional scale.

H.25: Matching Models to Measurements in the Up-Scaling of Carbon Exchange from Flux Sites to Regions

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It is a major problem of bottom-up scaling that in-situ flux observations are in general spatially limited and disparate. Thus, to achieve valid regional exchange rates, models must be used to interpolate and extrapolate over the spatial domain covered by these observations. Observed and modeled fluxes can only be linked if they represent exchange over ecosystems that are characterized in the same way. Because most long-term flux stations are not situated in spatially extensive homogeneous locations, this requirement is often a problem, but can be satisfied by selecting observation periods whose flux footprints are statistically representative of the type of ecosystem characterized in the model. The flux footprint function indicates the time-varying surface “field-of-view” (or spatial sampling window) of an eddy-flux sensor, oriented mostly in upwind direction. For each observation period, the modeled flux footprint window is overlaid over a high resolution vegetation index map (derived from Landsat or a better resolution platform), to determine a footprint-weighted vegetation index for which the observation is representative.

We demonstrate that the agreement between modeled and measured carbon exchange is improved considerably, if a flux-footprint matching criterion is used to constrain the data over which models are evaluated. This approach reveals that a large fraction of flux measurement vs. model uncertainty is attributable to the footprint mismatch, depending on the spatial scales of variability of the land cover. The result is an improved understanding of the sources of model uncertainty and better constrained bottom-up carbon exchange modeling capability.

H.26: Regional Carbon Dynamics in Southeastern US: Quantifying effects of multiple stresses on terrestrial ecosystems through data-model assimilation

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Terrestrial ecosystems in the southeastern United States have experienced a complex set of multiple changes in climate, atmospheric composition, land use and natural disturbances. Little is known about how these multiple changes have affected terrestrial carbon dynamics in the southeastern United States. In this study, we have examined how carbon fluxes and storage in southeastern United States have changed as a result of multiple stresses/changes and interactions among those stresses including land-cover change, climate variability, atmospheric composition (carbon dioxide and tropospheric ozone), precipitation chemistry (nitrogen composition), and natural disturbances using estimates of carbon fluxes and storage from factorial simulation experiments with the Dynamic Land Ecosystem Model (DLEM) in conjunction with remotely sensed and field data. Our analysis suggests that the net carbon exchange of terrestrial ecosystems with the atmosphere in this region show substantially interannual and spatial variations. Forest recovery after cropland abandonment and natural disturbances have resulted in an carbon uptake, but rapid urbanization and rising tropospheric ozone pollution have led to a significant reduction in carbon storage in the southeast. Land-use change appears to be an important control over regional carbon dynamics in this area.

H.27: Carbon Dynamics (1998-2001) in the Northern Great Plains Grasslands

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Carbon fluxes on rangelands are highly variable in space and time. Investigating the responses of rangeland carbon fluxes to climatic variations, shifts in management strategy, and the distribution of soil properties is important to understanding carbon dynamics. We investigated rangeland carbon dynamics across the northern Great Plains and identified carbon sink and source areas by employing a remote sensing-based piecewise regression model. The model estimated the regional net ecosystem exchange (NEE), gross primary production (GPP), and respiration by spatially extrapolating local flux tower measurements over regions. From 1998 to 2001, carbon fluxes in the study area were almost in equilibrium, with a small sink in 1999 (NEE = 16.8 $gCm^{-2}year^{-1}$) and small sources in 1998, 2000, and 2001 (-15.5, -59.4, and -6.0 $gCm^{-2}year^{-1}$, respectively). Significant local variability was likely related to climatic variations. The carbon sources associated with droughts and warmer temperatures were primarily a result of the reduction in GPP. Total ecosystem respiration was less sensitive to these same climatic variations. In the timeframe of this study, geographic patterns of carbon sinks or sources were apparent: carbon sources were more likely to occur in the drier western extents and carbon sinks occurred in the eastern extents and near the mountains in the far west.

H.28: Novel Non-Destructive Soil Carbon Analysis; II - Characteristics and Results

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Inelastic Neutron Scattering (INS) system for soil carbon measurement can be briefly described as a gamma ray spectroscopy induced by fast, 14 MeV, neutrons that interact with the nuclei of the elements present in the soil matrix. The INS system is non-destructive in which the neutron generator with the detection system are mounted on a cart about 30 cm above the ground. The system is operated in either stationary or scanning mode when towed over the field it provides a true mean value over the scanned area. The scanning is performed at typical speeds of 5 miles per hour although, depending on the surface roughness, can be moved at higher speeds. The volume probed by the system is several hundreds of kilogram depending on the soil bulk density and moisture. At present the INS system has been calibrated to measure carbon and it is planned to calibrate it to measure at the same time as carbon N, P, K, bulk density, and moisture. The system response to elemental concentration is linear and since it probes constant volume (saturation volume) it is directly proportional to the number of carbon atoms in that volume, i.e., carbon concentration, gC/cm3. The response function of the INS system can be expressed analytically as a multidimensional integral over space, energy and time and solved numerically using Monte Carlo method. Preliminary results from system simulations showing dependence on the soil bulk density and moisture together with the estimates of the sampled depth, footprint and volume are presented. Initial results of field stationary and scanning measurements are also included.

Continental Carbon Budgets and Analyses

I.1: The Relative Fine-Scale Flux Constraint Provided by Dense *In Situ* and Satellite-Based CO_2 Measurements, as Determined by a Variational Data Assimilation Scheme

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The relative sparseness of CO_2 measurements, both spatially and (until recently) temporally, has limited our ability to improve our estimates of surface sources/sinks of CO_2 and the carbon processes that drive them. Eddy flux towers are now providing insight into the diurnal and synoptic flux variability in the immediate vicinity of the towers, and aircraft campaigns can provide a more integrated regional view for short time periods, but for obtaining annually-integrated fluxes across large regions or continents, longer-term data at

dense spatial resolutions are needed, preferably across decadal spans. Analyzing such data in a global context allows the full power of the global constraint (the difference between the anthropogenic input and the atmospheric storage) to be applied, and atmospheric transport models allow the fluxes to be partitioned to regional scales.

Here we use such a global atmospheric inversion scheme (based on variational data assimilation) to assess the ability of several types of atmospheric CO_2 measurements to constrain the surface sources and sinks at sub-synoptic time scales and at the spatial scale of a global transport model (200-500 km on a side). First, we compare the expanding network of continuous in-situ analyzers (both of concentration and flux) to the predominantly flask-based network of five years ago. Then we compare both of these to the data expected from the Orbital Carbon Observatory (OCO), a satellite to be launched by NASA in 2008. Realistic measurement errors, vertical weighting functions, orbital geometry, and cloud and aerosol masking for two different pointing modes (nadir and glint) are analyzed. The relative merits of the spatially-dense, early-afternoon coverage of OCO and the spatially-sparse but fully-diurnal coverage of the *in situ* sites are compared. We also attempt to simulate the effects of several types of measurement biases that are expected to corrupt the satellite data.

I.2: Use of CO_2 vertical profiles from the NOAA/ESRL Aircraft Network to estimate carbon sources and sinks over continental North America in a direct carbon budgeting approach

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We estimate the net carbon dioxide (CO_2) surface flux over continental North America from the NOAA/ESRL Global Monitoring Division (GMD) Aircraft Network. The vertical CO_2 profiles made at 19 aircraft sites over the last 10 years are first interpolated using a geostatistical interpolation technique called Kriging which uses transport fields from weather analysis. The resulting gridded climatology of a single year displays clear signals of latitudinal, longitudinal and vertical gradients, which gives insights on the transport and sources of CO_2 over North America. The climatology is then used in a direct carbon budgeting flux estimation. Direct budgeting puts a control volume on top of North America, balances air mass in- and outflows into the volume and solves for the surface flux. This independent estimate will be compared with forward and classic inverse estimates of net North American flux.

I.3: Recent Trends in U.S. Forest Disturbance and Regrowth from Landsat and USFS FIA : A Contribution to the North America Carbon Program

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Understanding forest dynamics is critical to the goals of the NACP. Scaling local patterns of forest change to regional and continental areas will prove to be a significant challenge. As a result, mapping land-cover change and disturbance falls into the NACP's "First Tier" of land measurements - those measurements that must be made comprehensively at continental scales and, most likely, over a range of time periods, from remote sensing and allied comprehensive ground measurements such as the US Forest Service Forest Inventory and Analysis (FIA) data. In this study, we are building upon our previous work with land remote sensing measurements in combination with the USFS FIA field measurements, to develop a 30+ year historical record of forest disturbance and regrowth dynamics for North America, This analysis will provide carbon modelers with critical information is needed to both parameterize and validate regional- to continental-scale process models applied across North America.

I.4: Improved Fossil/Industrial CO2 Emissions Modeling for the North American Carbon Program

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The quantification of fossil fuel CO2 emissions has implications for a wide variety of scientific and policy-related questions. Improvement in inverse-estimated carbon fluxes, country-level carbon budgeting, analysis of regional emissions trading systems, and targeting of observational systems are all important applications better served by improvements in understanding where and when fossil fuel/industrial CO2 is emitted. Traditional approaches to quantifying fossil/industrial CO2 emissions have relied on national sales/consumption of fossil fuels with secondary spatial footprints performed via proxies such as population. This approach has provided global spatiotemporal resolution of one degree/monthly in addition to division by fuel type. In recent years the need has arisen for emission estimates that not only achieve higher spatiotemporal scales but include a process-level identification (cars, residential heating, lighting, etc).
We have embarked on a NASA-funded research strategy to construct a process-level fossil/industrial CO2 emissions model/database for North America that will resolve fossil/industrial CO2 emissions hourly and at 36 km.
Our approach builds from the many decades of air quality monitoring for regulated pollutants such as NOx, VOCs and CO that has been performed by regulatory agencies across the United States and reported to the Environmental Protection Agency (EPA). By using the highly resolved monitoring data supplied to the EPA, we have computed CO2 emissions for residential, commercial/industrial, transportation, and biogenic sources.
I will provide a description of the methodology we have employed, the difficulties encountered and some preliminary results. I will then compare our results to the traditional fossil/industrial CO2 emissions based on national sale/consumption statistics highlighting those areas where disagreement remains and next steps planned for resolving differences.

I.5: Daily Emissions of CO2, CO and CH4 from Biomass Burning in the U.S. in 2006 and the Impact on Air Quality

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We will present daily emission inventories of CO2, CO, and CH4 from biomass fires in the United States with a 1-km x 1-km resolution from January to December 2006. The computation assimilates (1) real-time MODIS data of Terra and Aqua satellites for fire locations and burned areas, (2) a vegetation map for the type of biomass burned, (3) a fuel map for the amount of available biomass burned in a unit area, and (4) the emission factors of CO2, CO, and CH4 from fires in various ecosystems. The results show that the emissions began in early January in the southeastern U.S., and reached southwestern U.S. in May. The fires and the emissions then spread from the south of the Rockies in May to the north in September.

The high-resolution emissions inventory is essential in quantifying the atmospheric chemical composition downwind from large fires. We will present the contours of CO, ozone, and PM2.5 concentrations with a 22-km resolution nationwide at the ground level and 500 mb on August 14-16, 2006. A case study of the Tripod Complex Fire in eastern Washington State also will be presented.

I.6: The forest sector carbon inventory of the United States, 1990-2005

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We present methods and results for the official forest sector carbon inventory estimates of the United States, published annually by the U.S. Environmental Protection Agency to meet requirements of the United Nations Framework Convention on Climate Change. Forest estimates are based on forest inventory data collected by the USDA Forest Service, Forest Inventory and Analysis Program, augmented with information from additional datasets and the FORCARB2 model. Carbon in harvested wood is estimated using the WOODCARB II model, based on wood products survey data and life cycle information. The sequestration potential of agroforestry systems is not currently included in the inventory, but has been identified as relatively large. Annual forest carbon stock change results are presented from 1990 to 2005. In 2005, forests were estimated to sequester a net of 186 Tg C/yr, with an additional 28 Tg C/yr continuing to be sequestered in harvested wood. Additional results presented include maps of carbon stocks and stock change.

I.7: Constituency: Mapping the Areas that Flux Towers Represent Best

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Presented will be an extension of our remote sensing-based network analyses to the concept of constituency for the AmeriFlux system of eddy flux towers. Until now, we have quantified how well the environmental conditions at a geographic network of flux towers represent all of the environmental conditions within the greater map that contain them. In so far as AmeriFlux represents the best set of fixed continental carbon flux measurements, every location must be represented (no matter how well or poorly) by measurements made at one of the existing flux towers. A map will be presented showing the tower (by color) which best represents each cell in the continental United States. We call this flux tower constituency, since each tower stands for the cells it best represents. A second map showing the degree of representation for each cell will also be presented. This second map quantifies how well each cell is represented by the flux tower which best represents it.

I.8: Understanding the Changing Carbon, Nitrogen, and Water Cycles in the Earth System

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Accurate predictions of the future climate and biogeochemistry of the Earth rely upon our ability to simulate the many complex interactions between ecosystems, the hydrosphere, and the atmosphere. These simulations must account for changes in forcing related to human activity and natural perturbations. Our research is focused on the development of a global-scale integrated mode of terrestrial and freshwater biogeochemical cycles (carbon, nitrogen, and water) in the context of changes in land-use, atmospheric chemistry, and climate. Remote sensing data from Terra/Aqua and other platforms is used for evaluation of predicted spatial and temporal patterns of key ecosystem characteristics and functioning.

I.9: CarbonTracker: An annual global inversion flux product from the NOAA Earth System Research Laboratory

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The Global Monitoring Division (GMD) of NOAA's Earth System Research Laboratory is launching a CO_2 flux product called CarbonTracker. Fluxes from CarbonTracker over the period 2000-2005 are estimated from over 27,000 atmospheric CO_2 mixing ratio estimates from GMD's sampling network, including discrete flask measurements from stations around the globe, continuous measurements at baseline observatories and tall towers in the United States, and data from Canadian collaborators. The inversion system is based on an advanced fixed-lag ensemble Kalman smoother. It uses a novel structure of "flux modules" in order to spread the influence of observations over 19 different terrestrial ecosystem types (Peters et al. 2005, 2007).
While CarbonTracker uses observations from around the world and produces global flux estimates, it has been designed to take advantage of the enhanced sampling density over well-observed regions. Its results are therefore most reliable over North America. The first release of CarbonTracker is scheduled for late December 2005, and the product will be updated annually. Flux estimates, flux maps, and numerical results are available both on the web and by request.

I.10: North America Terrestrial Carbon Budget: A Model Analysis of the Combined Effects of CO2, Nitrogen, Climate, Land Use Changes and Management

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Several mechanisms have been proposed to explain present trends in the terrestrial uptake of CO2. These mechanisms include physiological responses of terrestrial ecosystems to increasing ambient CO2 concentrations, anthropogenic N deposition, and variations in productivity due to climate variability and changes in land-use and management. Each of these mechanisms may be playing a significant role in the global CO2 budget. In addition, changes in soil management can potentially increase the accumulation of soil organic carbon (SOC) in addition to anthropogenic disturbances, which include clearing of land for agriculture, conversion of forest to pasture, and harvest of forest products. We present the concurrent effects of all important ecosystem processes and anthropogenic disturbances and management practices on North America terrestrial carbon budget, for the historical period 1900-2000, using an Integrated Science Assessment Model (ISAM), a geographically explicit advanced terrestrial ecosystem model which simulates the carbon and nitrogen fluxes to and from different compartments of the terrestrial biosphere with 0.5-by-0.5 degree spatial resolution.

I.11: The National Biomass and Carbon Dataset 2000: A high-resolution baseline of conterminuous U.S. Biomass and Carbon Stocks from InSAR/Optical Fusion

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A major goal of the North American Carbon Program (NACP) is to develop a quantitative scientific basis for regional- to continental-scale carbon accounting to reduce uncertainties about the carbon cycle component of the climate system. In support of this goal, the objective of this project is the quantification of terrestrial carbon stocks held in aboveground live biomass at an unprecedented spatial resolution for the conterminuous U.S. Given the complementary nature and quasi-synchronous data acquisition of the 2000 Shuttle Radar Topography Mission (SRTM) and the Landsat-based 2001 National Land Cover Database (NLCD) and LANDFIRE project, an exceptional opportunity exists for exploiting data synergies afforded by the fusion of these high-resolution data sources. Models to estimate vegetation height and subsequently aboveground live biomass and carbon stocks are driven by the InSAR and optical datasets with response variables derived from the national network of Forest Inventory and Analysis (FIA) plots as well as airborne lidar data sets. Results were produced for three out of some 60 NLCD ecoregional mapping zones: Based on data derived from nearly400 FIA plots in mapping zone 16 (Centeral Utah), we obtained estimates for height and biomass where r=0.91 (RMSE=1.7 m) and r=0.80 (RMSE=34 tons/ha), respectively In mapping zone 60 (Chesapeake Bay Area) validation on 377 samples produced height and biomass predictions where r=0.79 (RMSE=3.5 m), and biomass r=0.65 (RMSE=56 tons/ha), respectively. Validation on 918 samples in mapping zone 55 (Southern Georgia/Northern Florida) resulted in height estimates with r=0.76 (RMSE=3.8 m), and biomass estimates with r=0.78 (RMSE= 46 tons/ha).

I.12: Sampling for national-level estimates of trends in forest disturbance and regrowth

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Forest disturbance and regrowth dynamics are important parts of the North American carbon budget, but these processes operate at a spatial grain finer than can be tracked accurately with the coarse-grained remote sensing products typically used for national-level estimation. Here, we describe a stochastic sampling strategy based on Landsat scenes that will be used to provide biennial estimates of national trends in forest disturbance and regrowth from the early 1970s to present. The sample was required to meet several competing goals, including capture of diverse forest types and disturbance regimes, minimization of effort expended in low-forest-area scenes, flexibility for expansion of the sample size in the future, and preferential inclusion of scenes where significant prior research had been accomplished. Sample units were defined as the non-overlapping area of Landsat scenes on the WRS-2 grid, were divided into eastern and western sample frames, and were attributed with forest type and area from a recent national-level forest type map. For each frame, 100,000 randomized, ordered lists of scenes were chosen and scored according to the competing goals of the project using a target number of samples in the east and the west. The minimal set of these lists that best balanced all goals and that included each scene in the frame at least once was identified, and from this set a single ordered list was randomly chosen. Probabilities of inclusion for each scene were calculated from the proportion of lists from the final set that included that scene. This strategy allows use of unequal-probability estimators in a design-based estimation paradigm, while also ensuring that a full range of conditions can be used in a model-based or model-assisted estimation paradigm.

I.13: Mapping Incident Photosynthetically Active Radiation over North America

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Incident photosynthetically active radiation (PAR) is a key variable required by almost all terrestrial ecosystem models. Unfortunately, the current incident PAR products estimated

from remotely sensed data at spatial and temporal resolutions are not sufficient for carbon cycle modeling and various applications. In this study, we are generating both instantaneous and daily incident PAR from the polar-orbiting Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectrometer (MODIS) and Geostationary Operational Environmental Satellite (GOES) data at 1km and 4km spatial resolutions. The algorithms, extensive validation results and product characteristics will be presented.

I.14: Developing the Improved Land Surface Biogeophysical Products over North America

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The land surface carbon models require extensive products for initialization, assimilation and validation, some of which have to be generated from remote sensing. The current NASA Earth Observing System (EOS) land surface products are discontinuous in both space and time. Their uncertainties have not been well characterized. In this study, we are 1) producing spatially and temporally continuous land surface parameter fields (e.g., albedos, leaf area index); 2) generating the climatologies of these variables based on the plant functional types; 3) characterizing the uncertainties of these products through extensive validation using "ground-truths" and product inter-comparisons; and 4) improving these products using a prototype remote sensing data assimilation system.

I.15: Constraining North American Fluxes of Carbon Dioxide and Inferring their Spatiotemporal Covariances through Assimilation of Remote Sensing and Atmospheric Data in a Geostatistical Framework

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This poster presents preliminary work from a new project which will use remote-sensing data and atmospheric measurements in a geostatistical inverse modeling framework to quantify North American surface fluxes of carbon dioxide at high spatiotemporal resolution. The proposed approach will estimate the magnitude of these fluxes without relying on prior flux estimates, and will account for the uncertainties and covariances associated with measurement and transport errors and flux distributions. In addition, we will evaluate the influence of remote-sensing derived auxiliary environmental data on flux estimates. This approach will enable more accurate flux accounting and will also provide process-based understanding of flux variations. This process- based understanding will be useful when compared to biospheric model parameterizations. Preliminary results using real atmospheric data suggest that LAI, FPAR, and synoptic scale meteorological parameters explain a significant amount of biospheric flux variability at the global scale. Synthetic data experiments using a repeating monthly-mean diurnal flux cycle at the scale of North America show that the technique is able to accurately recover monthly average NEE and the monthly- average diurnal cycle of NEE for large portions of the continent at $1° \times 1°$ resolution.

I.16: Perpetual Growth, or Potential Catastrophic Dieback of North American Forests?

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The MAPSS team participated in the VINCERA (Vulnerability and Impacts of North American forests to Climate: Ecosystem Responses and Adaptation) project. VINCERA was designed to intercompare three dynamic general vegetation models (DGVMs) over most of North America using three General Circulation Models (GCMs), each of which simulated future climate under two different greenhouse gas emissions scenarios. The comparison between two of the DGVMs, MC1 and SDGVM, will be presented. The two DGVMs behaved similarly over 100 years of historical climate, but diverged dramatically under all future scenarios. SDGVM simulated increased productivity and carbon sequestration through 2100. MC1 originally showed increases, but then simulated dramatic declines in most forested ecosystems. The differences are due to minor uncertainties (< 1%) in large fluxes of carbon going in to and coming out of ecosystems. The primary uncertainties accounting for the differences between the two models are in 1) the relative strength of the effects of elevated CO2 concentration on plant water-use-efficiency and productivity and 2) in the approach to simulating wildfire. Increasing the strength of the CO2 effect in MC1 (via a beta function) significantly mitigated the carbon losses under the future climate scenarios. However, the simulation of wildfire in MC1 had to be nearly completely subdued in order to bring the two models into near parity. Under some future scenarios, in the absence of fire suppression/exclusion, much of the eastern U.S. forest and the southern reaches of the Boreal Forest are converted to non-forest under catastrophic disturbance.

I.17: Terrestrial ecosystem nowcasts and forecasts for North America

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Achieving NACP goals requires integration of a number of data sources that are both point-based, as in the case of tower and station measurements, and spatially explicit, as in the case of satellite data, and models to produce ecosystem fluxes that are developed at a variety of spatio-temporal scales. Our data and modeling system, the Terrestrial Observation and Prediction System (TOPS), is being used over North America to produce nowcasts (daily) and forecasts (up to 7 days) of ecosystem fluxes including gross and net primary production and net ecosystem exchange. Nowcasts and forecasts are evaluated using observations from diverse networks: SNOTEL for snow cover, USGS/Streamflow for runoff, USDA/SCAN for soil moisture, GLOBE for phenology and FLUXNET for carbon/water fluxes. Though measurement theory has well-established methods for describing the bias and precision involved in data streams at one location within a network, an incomplete theory exists for the reporting of uncertainty from the type of spatially explicit, "bottom-up" model results central to the TOPS approach. Existing theory includes the characterization of instrument error through the calibration process, propagation of measurement error through model equations, description of model parameter error also through calibration, and interpolation error estimated through geostatistical theory. This set of approaches is sufficient assuming that all input and output variables are based on consistent spatial and temporal resolutions. The fact that heterogeneous resolutions are used in NACP has been referred to as the “scale mismatch” problem and is a form of the “change of support” problem. We discuss the characterization of uncertainty for TOPS including both quantifiable and poorly known aspects. Further, we consider the question of which approach is less error-prone: interpolating first, then predicting instead of predicting first, then interpolating. Improvements in the reporting of recognized bias and precision parameters would allow the application existing theory to evaluate increases in accuracy achieved by NACP.

I.18: Forest FACE Synthesis Project: Net Primary Productivity

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Climate change predictions from models are highly dependent on assumptions about feedbacks between the biosphere and atmosphere. One critical feedback occurs if C uptake by the biosphere, or its net primary productivity (NPP), increases in response to the fossil-fuel driven increase in atmospheric [CO_2] (“CO_2 fertilization”), thereby slowing the rate of increase in atmospheric [CO_2]. With the objective of better informing ecosystem and global models that include a feedback between terrestrial biosphere metabolism and atmospheric [CO_2], we analyzed the response of NPP to elevated CO_2 (~550 ppm) in four free-air CO_2 enrichment (FACE) experiments in forest stands. The forest stands represent a broad range of productivity, climatic and soil conditions, stand developmental history, and life history characteristics of the dominant species, although all four are young stands in the temperate zone. We show that the response of forest NPP to elevated [CO_2] is highly conserved across a broad range of productivity, with a stimulation at the median of 23 ± 2%. The surprising consistency of response across diverse sites provides a benchmark to evaluate predictions of ecosystem and global models and allows us now to focus on unresolved questions about carbon partitioning and retention, and spatial variation in NPP response caused by availability of other growth limiting resources.

I.19: Canopy Nitrogen and Carbon Assimilation Across a Network of NACP - AmeriFlux Sites

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Carbon and nitrogen cycles in terrestrial ecosystems are tightly coupled through a shared set of biological processes. Despite the well-known influence of nitrogen availability on

fluxes of carbon, few studies have explicitly examined the role of nitrogen as it pertains to spatial and temporal variation in carbon cycling. This is due, in part, to limited crossover between different scientific communities, but also stems from some very real methodological limitations that make regional-scale assessment of N status difficult.

Here, we report on an investigation that examines the degree to which rates of carbon assimilation and growth in forests can be related to both local and regional variation in ecosystem N status. Field measurements from a series of forested research sites within the AmeriFlux network have been combined with hyperspectral remote sensing data from the AVIRIS and Hyperion instruments. Results from a cross-site synthesis indicate a positive relationship between canopy N and the maximum rate of carbon assimilation, as measured by flux towers. Because existing methods of canopy N detection are restricted to small landscapes, a parallel investigation involves developing generalizeable canopy N detection methods that would enable regional to continental application of these results. Results of this effort show that a substantial fraction of the variation in canopy N can be related to simple spectral features available from broad-band sensors.

I.20: Sensitivity of carbon dioxide fluxes to soil moisture in a coupled regional model

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We coupled a regional climate model (MM5), a crop modeling system (CMS), and a land surface model (LSM) into a climate-ecosystem model. A series of sensitivity experiments were carried out to evaluate the coupled model skill in simulating CO2 fluxes over the U.S. agroecosystem during the growing-season. Results showed that soil moisture, one of the least accurate variables in meteorological models, has largest effect on model-simulated CO2 fluxes. The model's common dry bias inhibits realistic photosynthesis rates through soil water stress and at the same time promotes soil microbial respirations caused by high temperature. Key tunable photosynthesis parameters and respiration dependencies on soil moisture were adjusted to account for model soil dry bias and thus to improve model performance. In addition, realistic specification of land use, especially the proportional area devoted to C4 plants, significantly improved the carbon flux simulations as compared with AmeriFlux data. Finally, the coupled model, with various land use and cropping management strategies for the US Midwest, was used to project carbon cycles under future scenario climates.

I.21: Terrestrial Carbon Sinks for the United States Predicted from MODIS Satellite Data and Ecosystem Modeling

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A simulation model based on satellite observations of monthly vegetation cover from the Moderate Resolution Imaging Spectroradiometer (MODIS) was used to estimate monthly carbon fluxes in terrestrial ecosystems of the conterminous United States over the period 2001-2004. Predicted net ecosystem production (NEP) flux for atmospheric CO2 in the U.S. was estimated as annual net sink of about +0.2 Pg C in 2004. Regional climate patterns were reflected in the predicted annual NEP flux from the model, which showed extensive carbon sinks in ecosystems of the southern and eastern regions in 2003-2004, and major carbon source fluxes from ecosystems in the Rocky Mountain and Pacific Northwest regions in 2003-2004. As demonstrated though tower site comparisons, NPP modeled with monthly MODIS Enhanced Vegetation Index (EVI) inputs closely resembles both the measured high- and low-season carbon fluxes. Modeling results suggest that the capacity of the NASA-CASA model to use 8-km resolution MODIS Enhanced Vegetation Index (EVI) data to predict peak growing season uptake rates of CO2 in irrigated croplands and moist temperate forests is strong.

I.22: Innovative uses of MODIS data to assess gross primary productivity and respiration of North American ecosystems

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Light use efficiency (LUE) models for estimation of ecosystem carbon exchange have proved to be difficult to parameterize because of uncertainties in the spatial and temporal variations of LUE. In this study we examined whether the enhanced vegetation index (EVI) and land surface temperature (LST) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) can be used directly to estimate gross primary productivity (GPP) and respiration (Re) of ecosystems at eddy covariance flux tower sites across North America. Previously we have reported a good general relationship between EVI and GPP across multiple sites. Here we examined the reasons for variation in the strength of this relationship between sites, as well as the mechanistic basis for this relationship. We also tested whether Re can be estimated using a model that couples EVI and LST. Our results showed that the correlation between EVI and GPP remains high through most of the range in vegetation greenness, whereas the seasonal variation in EVI was best explained by the severity of summer drought. Inclusion of photosynthetically active radiation (PAR) in the model improved the correlation with GPP for most of the evergreen sites but not for the deciduous sites. The respiration model showed the potential of estimating Re exclusively from EVI and LST, especially for the deciduous sites. These results demonstrate that remote sensing based carbon balance models can be considerably simplified for most vegetation types across North America without direct consideration of LUE.

I.23: Climate impacts of North American carbon sinks

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Mechanisms responsible for terrestrial carbon sinks across North America have inseparable consequences for other forcing agents including albedo, aerosols, and other greenhouse gases. In many cases, the net climate impact of these different agents remains unknown. We illustrate the climate tradeoffs between carbon accumulation and decreasing surface albedo for a fire chronosequence in interior Alaska and a precipitation gradient in Southern California. These examples show how integrating carbon cycle science with other elements of the U.S. climate change science program is crucial for the design of successful sequestration and mitigation strategies.

I.24: Historical Influence of Soil and Water Management on Carbon Erosion and Burial in the United States

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The documented history of U.S. soil and water management provides a unique opportunity to examine soil and sediment carbon storage under conditions of changing management practices. The present-day carbon budget associated with erosion and burial cannot be determined without quantifying the time-dependent changes due to past and present soil and water management.
We have utilized existing datasets with GIS and modeling techniques to estimate sediment and carbon budget trends since the year 1700 in the conterminous U.S. Like many previous studies, our analysis indicates that historical export of sediments to coastal areas is relatively insignificant, whereas substantial sediment deposition in upland areas is necessary to balance the historical sediment budget. We apply models of carbon dynamics to time-dependent accounting of carbon in erosional and depositional environments. Rates of soil carbon production, erosion, degradation, transport, and burial are constrained by both sediment and carbon mass-balance coupled to representations of landscape soil-carbon dynamics. We find that cumulative amounts of carbon affected by historical erosion and deposition are comparable to amounts of cumulative soil carbon depletion estimated in previous studies that have not considered erosion and deposition.
Our historical sediment budget scenarios imply a large historical transient of eroded and redeposited terrestrial sediments. An improved understanding of non-steady-state carbon dynamics in these sediments is needed to estimate the net effect of erosion and deposition on the historical and present-day exchange of carbon between the land and the atmosphere.

I.25: Comparison of Two U.S. Power-Plant Carbon Dioxide Emissions Datasets

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Estimates of fossil-fuel consumption and CO_2 emissions are recorded at each power-plant point source, therefore U.S. power-plant CO_2 emissions (8-9 percent of global fossil-fuel CO_2 emissions) may be the most thoroughly monitored globally significant source of fossil-fuel CO_2 emissions. We compared two datasets for the years 1998-2000: (1) the Department of Energy/Energy Information Administration (EIA) dataset of emissions calculated from fuel data contained in EIA electricity database files, and (2) eGRID (Emissions and Generation Resource Integrated Database), a publicly available database generated by the Environmental Protection Agency. We compared the eGRID and EIA estimates of CO_2 emissions for electricity generation at power plants within the conterminous U.S. at two levels: (1) estimated individual power-plant emissions, which allowed analysis of differences due to measurement method, plant type, and calculation method; and (2) estimated conterminous U.S. totals for power-plant emissions, which allowed analysis of the aggregated effects of these individual plant differences, and assessment of the aggregated differences in the context of previously published uncertainty estimates. At the individual plant level, the average difference (absolute value) between eGRID and EIA estimates is approximately 12 percent, relative to the means of the paired estimates. Systematic differences are apparent in the eGRID and EIA reporting of emissions from combined heat and power plants. Additional differences between the eGRID and EIA datasets can be attributed to the fact that most of the emissions from the largest plants are derived from a Continuous Emissions Monitoring (CEM) system in eGRID and are calculated using fuel consumption data in the EIA dataset. This results in a conterminous U.S. total calculated by eGRID that is 3.3 to 5.8 percent (21 to 35 teragrams carbon) larger than that calculated by EIA.

I.26: A high-resolution daily surface weather database for NACP investigations

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Work is underway to produce a database of daily surface weather fields at high resolution (1 km) over all of North America, suitable for use in driving forward (prognostic) models

of terrestrial ecosystem processes. The database includes daily maximum and minimum temperature, daily total precipitation, daily average water vapor pressure, and incident shortwave radiation. A major challenge for this effort is the acquisition and integration of existing datasets from Mexico, Canada, and the United States. Here we describe preliminary efforts to integrate several large subsets of the international data sources. We also outline the requirements for a complete integration and describe the benefits to a Joint NACP effort.

I.27: The human carbon budget: the spatial distribution of carbon consumption and release in the US

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Food and forest products are grown in agricultural and forested regions and transported to areas of human and animal concentration. Regional carbon budgets are unbalanced to the extent that carbon is taken up by crops and released elsewhere within a country or beyond. Cias et al.(2001) concluded that this "horizontal displacement is far from negligible and it has a large impact on the spatial (and temporal) distribution of carbon fluxes over large areas…" Koerner and Klopatek (2002) estimated that 1.6% of the C input to the atmosphere in a large metropolitan area (Phoenix) was from human respiration. In a project that will ultimately characterize the total lateral and temporal displacement of C in the US as a result of the harvest and use of agricultural and forest products, we have balanced the C budget for an individual (as a function of age, gender, and race). We have also estimated the spatial distribution of US emissions (at ≈ 400 m resolution) attributable to human metabolism. The average US adult has a C content of 20.7 kg C and consumes 67 kg C yr-1, of which 59 kg are respired as CO2, 7 kg are excreted as liquid and solid waste, and less than 1 kg is released as flatus, sweat, etc. For the US average, per capita consumption of food carbon is 1.3% of per capita consumption of fossil-fuel carbon. In areas of concentrated population, CO2 from human respiration can be several times the national average of fossil-fuel emissions per km2.

I.28: A One-Dimensional Study of Cumulus Convection in the Diurnal and Seasonal Atmospheric CO_2 Budgets Over the Southern Great Plains

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We compare observations of the diurnal and seasonal cycles of surface CO_2 flux to a boundary layer budget model. The data is collected from eddy covariance and precision gas system measurements on a 60 m tower at the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) near Lamont Oklahoma, and from the RUC (Rapid Update Cycle) model initialization of boundary layer meteorological variables. Observations of cloud boundaries and frequencies are obtained from the ARM Millimeter Wavelength Cloud Radar and Clothiaux algorithms. We use a stable boundary layer model to diagnose nocturnal surface CO_2 flux, and a convective boundary layer model for daytime fluxes. The study uses boundary layer heights and the level of free convection as criteria for the lower and upper extent of actively venting cumulus, and convective scaling velocities as approximate cumulus updraft velocities. Seasonal averages of budget terms show that the diurnal covariance between boundary layer height and local changes in CO_2 concentration explains the magnitude of the diurnal cycle, and a significant portion of the seasonal cycle of surface CO_2 flux. The budget model composite diurnal cycle closely resembles the observed diurnal cycle for winter and spring, with observed magnitudes of 5 µmol /m^2s and 10 µmol /m^2s in winter and spring, respectively. In summer and early fall, the model without cumulus convection overpredicts surface uptake by up to 14 µmol/m^2s. Preliminary results attribute more than half of the discrepancy between modeled and observed fluxes to enhanced boundary layer entrainment in the presence of cumulus convection.

I.29: The 1998-2002 North American drought and the anomalous CO2 growth in 2002-2003

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A rare drought occurred from 1998 to 2002 across much of the Northern Hemisphere midlatitude regions. Using observational data and numerical models, we analyze the impact of this event on terrestrial ecosystem and the global carbon cycle. The biological productivity in these regions was found to decrease by 0.9 PgC yr(-1) or 5% compared to the average of the previous two decades, in conjunction with significantly reduced vegetation greenness. The drought led to a land carbon release that is large enough to significantly modify the canonical tropically dominated ENSO response. An atmospheric inversion reveals that during the 1998 - 2002 drought period, Northern Hemisphere midlatitude changed from a 1980 1998 average of 0.7 PgC yr(-1) carbon sink to nearly neutral to the atmosphere, while a forward model suggests a change of 1.3 PgC yr(-1) in the same direction. This large CO2 source may explain the consecutive large increase in atmospheric CO2 growth rate of about 2 ppmv yr(-1) in recent years, as well as the anomalous timing of events. This Northern Hemisphere CO2 anomaly was largely caused by reduced vegetation growth due to less precipitation, but also with significant contribution from higher temperature that directly increases respiration loss and indirectly further reduces soil moisture. Since the Northern Hemisphere midlatitude landscape has been significantly

modified by agriculture, grazing, irrigation and fire suppression, the strong signature in the global carbon cycle of a drought initiated by changes in tropical oceanic temperatures is a remarkable manifestation of climate variability, with implications for carbon cycle response and feedback to future climate change.

I.30: Can remotely sensed canopy heights be used to improve MODIS-based estimates of ecosystem carbon balance?

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A number of models use canopy-reflectance data derived from sensors such as MODIS to estimate large-scale ecosystem GPP or carbon balance. However, forest carbon dynamics depend on disturbance and land-use legacies, and in particular successional stage is thought to strongly influence gross primary productivity (GPP) and respiration (R). At present, reflectance based models neglect these aspects of ecosystem structure (unless this may be implicitly captured in canopy reflectance).

The Geoscience Laser Altimeter System (GLAS), on board of the ICESat satellite, can register canopy height as well as canopy density throughout the canopy, giving insight into forest successional state. We here explore whether the incorporation of GLAS-derived canopy height information can be used to improve MODIS-based estimates of carbon balance. We test this idea by combining a MODIS remote-sensing driven model of surface carbon fluxes, the Vegetation Photosynthesis and Respiration Model (VPRM) (Mahadevan et al., 2006), with GLAS height data, and compare to measurements of ecosystem carbon flux across a boreal chronosequence of eddy flux towers.

I.37: An integrated carbon model (ITCM) for North America: Constraining process models with experiments and measurements for analysis and projection.

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To further advance terrestrial carbon cycle science, observations and measurements must 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. Only through such integration may we produce reliable estimates of sources and sinks of CO2 and extrapolation from observations in space and time to novel environmental conditions of the future. Thus the overarching goal is to develop and demonstrate an operational framework in which observational studies addressing different aspects of terrestrial carbon processes and modeling activities at different spatial and temporal scales are integrated in a mutually reinforcing relationship, and used to estimate and mechanistically explain current carbon sources and sinks and forecast their future behavior and influence on atmospheric CO2 concentration and climate. We focus on North America, but the improved understanding and forecasting skill acquired through improved data-model integration have global applications.
The research tasks begin with site-scale data assimilation with computationally intensive FAPIS is already underway with previous funding. For regional data assimilation we will use the computationally less demanding LoTEC model combined with DAYCENT for natural ecosystems, and Agro-IBIS for agricultural systems. By starting with models that are fundamentally complete in terms of primary process representations and available, we can proceed at regional scales with parameter identification and parameter uncertainty estimation using data assimilation methods, integrate with regional data bases and perform bottom-up carbon cycle analyses for timely use in NACP synthesis activities. Finally, the integrated data-modeling system can be combined with CO2, climate, and other environmental forcings (N deposition, O3 concentration) to make continental to global scale carbon cycle forecasts. The integration framework considers that the proposed ITCM can be integrated into a land-surface component for utilization in Earth System Models (ESMs).

I.38: Towards Robust Carbon Budget Estimates for North America

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The Weather Research and Forecast (WRF) model has been adapted to provide meteorological support for the North American Carbon Program. Our primary goal is to generate robust estimates of the carbon fluxes in North America using a Lagrangian approach in which the influence functions computed using the STILT model are convolved with the biosphere fluxes computed the VPRM model, the latter being driven by both the WRF-produced and satellite-based estimates of solar fluxes and surface temperatures. An initial set of WRF/STILT/VPRM simulations during the summer of 2004 is being evaluated using CO2 observations collected during the COBRA campaign. The effects of grid

resolution are examined by comparing results from an outer 40 km grid with those using an inner 8km nest, and results are compared with STILT computations using alternate meteorological datasets (using operational analysis fields and mesoscale simulations from BRAMS) as drivers for STILT and VPRM. The extent to which mass conservation is preserved in these meteorological inputs is evaluated using both in-line diagnostics of mass divergence of the mean wind fields, and tests of the well-mixed criterion using forward-backward calculations. With the release of WRF version 2.2, and the availability of FDDA (both analysis and observation nudging) in WRF, we plan to examine the effect of data assimilation on the fit to observed CO2 concentrations and the conservation of mass. This will contribute to the design of a DAS for carbon.

Wednesday, January 24

Carbon Management and Decision Support

J.1: Linking Landscape-Scale Carbon Monitoring with Forest Management

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We are integrating intensive ground-based measurements, remote sensing, and modeling at seven landscape-scale research sites across the U.S. to estimate carbon stocks and fluxes for forest carbon pools. As part of the North American Carbon Program, this study is intended to tie the spatially extensive, but coarsely resolved, measurements made through remote sensing and forest inventory to the spatially intensive and highly resolved measurements made at intensive monitoring sites such as the AmeriFlux network. Each study site consists of a diverse landscape that reflects the effects of natural disturbances and/or forest management activities on carbon stocks and productivity. To demonstrate the relevance of this work to land managers, we are evaluating how this information can improve decision support tools for estimating and reporting carbon stocks and changes in carbon stocks. The main products of this research include precise statistical estimates and maps of carbon stocks and productivity for a variety of forest landscape conditions; improved process models at ecoregion and stand scales; and decision-support tools for land managers interested in carbon management. We will estimate NPP and NEP for managed or disturbed tree stands in various stages of development, which will improve the ability of land managers to update or project stand-level inventories of carbon stocks for project evaluation and reporting to greenhouse gas registries. Reference data from these sites can be used by the scientific, policy, and land management communities. If successful, this project may evolve into a larger network of landscape-scale monitoring sites.

J.2: Recursive Calibration of Ecosystem Models Using Sequential Data Assimilation

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The specification of model parameter values needed to characterize a system is a fundamental issue in contemporary ecosystem science. Conventional inversion methods, which treat observations as a whole, lack the flexibility to investigate possible temporal evolution of the model parameters. This research developed a smoothed ensemble Kalman filter (SEnKF) to simultaneously estimate system states and model parameters when new observations become progressively available over time. The performance of the SEnKF was demonstrated in two case studies: (1) the assimilation of measurements of carbon exchange between a mixed forest and the atmosphere at Howland, Maine (USA), into a simple carbon flux partition model, and (2) the assimilation of estimates of net primary production into an ecosystem model --- the erosion deposition carbon model (EDCM).
Our analyses demonstrated that some model parameters, such as light use efficiency and respiration coefficients, were highly constrained by eddy flux data at daily to seasonal time scales. Light use efficiency was strongly seasonal. Model predictions based on parameters modified by the SEnKF were much improved, compared to predictions made without progressive data assimilation. The SEnKF reduced the variance of state variables that is caused by uncertainties of parameters and driving variables. Using SEnKF, the maximum net production rate, a key static parameter in the forest submodel in EDCM, actually varied with time. The analysis of net ecosystem exchange of carbon between the forest and the atmosphere was improved significantly, suggesting that the SEnKF is a robust and effective algorithm for recursive calibration of ecosystem models.

J.3: Trends and Uncertainties of Regional Carbon Stocks and Fluxes in the United States: Upscaling From Sites Using Data Assimilation

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Upscaling the spatial and temporal changes of carbon stocks and fluxes from sites to large areas is a critical step toward improved understanding and quantification of the dynamics of carbon sources and sinks over large areas. Although various modeling approaches have been developed to facilitate the upscaling process, few deal with error transfer from model input to output, and error propagation in time and space. In this study, we used the General Ensemble Biogeochemical Modeling System (GEMS) to quantify, with measures of uncertainty, the contemporary trends of carbon dynamics in selected regions of the United States. Model simulations were constrained using nonsequential and sequential data assimilation techniques and various observations, including fine-resolution (60-m) land cover change information derived from Landsat imagery, estimates of net primary productivity from the Moderate Resolution Imaging Spectroradiometer (MODIS), grain yield and cropping practices from the U.S. Department of Agriculture (USDA), and forest characteristics from the USDA Forest Service's Forest Inventory and Analysis database. Results indicated that the inter-annual variability of regional carbon sources and sinks is strongly affected by climate variability and to a lesser degree by land use change. Uncertainty in the estimated carbon stocks and fluxes varied in space and time with variable type (e.g., stocks, fluxes, etc.), ecosystem type (e.g., forest, cropland, etc.), land use change rate, and input data uncertainty.

J.4: Net primary production in the Mid-Continent region: comparison of two models versus surveys at the county scale

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The overall goal of our research project is to develop an integrated remote sensing simulation system that more accurately accounts for CO2 fluxes between agricultural lands and the atmosphere. One preliminary step was to carry out model-data net primary production (NPP) intercomparisons for a variety of agricultural systems - various crops, locations, and management. Here we present results from a comparison of annual model output from the Century and CASA (Carnegie-Ames-Stanford-Approach) models with survey data from the National Agricultural Statistics Service (NASS). This work was conducted for irrigated and non-irrigated corn, soybeans, and small grains (wheat and oats) at the county scale across Nebraska and Iowa for the years 2001-2004. NASS yield data were converted to NPP using dry matter conversions, aboveground residue to yield relationships, and average root:shoot ratios derived from numerous published sources. Net primary production in the CASA model was calculated monthly as a function of the amount of radiation intercepted by vegetation (derived from MODIS NDVI) modified by temperature and moisture scalars. The Century model simulates plant production by scaling genetically defined maximum monthly production depending on soil temperature, soil moisture status, and shading by dead vegetation. Whole county summaries of NASS NPP agree closely with previously published data. Preliminary results indicate better agreement between NASS, CASA, and Century estimates annual NPP for soybeans than for corn or small grains. Across counties the range of CASA estimates for corn NPP tended to be substantially less than NASS-based estimates and Century simulations for both irrigated and non-irrigated, with the largest differences in counties/years with high NPP. We are currently investigating potential causes of the observed responses by assessing simulated monthly NPP by crop for large-plot agricultural experiments.

J.5: Soil Carbon Sequestration in the U.S. Corn Belt

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Terrestrial carbon sequestration has a potential role in reducing the recent increase in atmospheric carbon dioxide (CO2) that is, in part, contributing to global warming. The path to stabilization of the carbon cycle and, ultimately, reduction in the concentration of atmospheric CO2 is though a regime of carbon management. The most stable long-term surface reservoir for carbon is the soil. Crop and grazing lands can be managed for both economic productivity and carbon sequestration. Land-use and soil management (including tillage and crop rotations) affect permanence of carbon storage by altering the processes governing carbon dynamics across landscapes. The EPIC-Century biogeochemical model was selected to study the long term impact of soil and crop management practices on soil carbon sequestration in central Iowa. Spatial information of the landuse/landcover from satellite sensors offers a great potential for studying the soil carbon sequestration over time and space. This study was designed to develop the baseline soil carbon and the impact

of management practices on soil carbon sequestered over the past 30 years and projection for the next 30 years. The model was initiated in 1975 with the STATSGO and model simulations were conducted at daily time step and at a grid-cell level of 1.6 x 1.6 km2. The soil and crop management practices were gathered from existing database. The model simulations show the changes in soil carbon in the top 20 cm various tillage practices and residue management.

J.6: Coupling Biogeochemical and life cycle greenhouse gas (GHG) models to manage GHG budgets of the biological and industrial system

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The objective of this study was to couple a biogeochemical model (BIOME-BGC) and a greenhouse gas life cycle inventory model for wood and paper products to estimate the net C system (i.e. biological + industrial) budget for the Chequamegon-Nicolet National Forest (CNNF). BIOME-BGC simulates carbon, water and nitrogen dynamics for terrestrial ecosystems, and is driven by remotely sensed data. We developed carbon life-cycle inventories of the harvest process on a major forest ownership and developed carbon life-cycle inventories for a dimensional lumber, paper for magazines, and oriented strand board (OSB) mills. The analysis included the harvest, primary mill, secondary mill, product use, and product disposal processes of the industrial forest carbon cycle for the CNNF. Present day statewide soil carbon estimated from STATSGO data ranged from 0.5 to 23.0 kg C m-2 with a mean of 7.3. County-wide estimates of total forest carbon estimates from FIA data ranged from 17.6 to 37.4 kg C m-2 with a mean of 23.8. Mean simulated statewide forest carbon sequestration (biological) increased from 0.026 kg C m-2 year-1 to 0.04 kg C m-2 year-1 for present day and anticipated climate change scenarios, respectively.The normal harvest with a climate change scenario had the highest carbon sequestered for 100 years (0.174 kg C m-2 year-1) followed by no harvesting with climate change (0.16 kg C m-2 year-1). Average carbon emissions over 100 years represented by the industrial budget (normal harvest scenario) comprised 5% of carbon sequestered by the CNNF for the same time period. Simulation results suggest that forest management activities could be adjusted to maximize long term forest carbon sequestration and minimize emissions from industrial processes

J.7: SOCCR: The State of the Carbon Cycle Report; U.S. Climate Change Science Program Synthesis and Assessment Product 2.2

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The first State of the Carbon Cycle Report (SOCCR), The North American Carbon Budget and Implications for the Global Carbon Cycle, is scheduled for release as U.S. Climate Change Science Program Synthesis and Assessment Product 2.2 in March 2007. The two broad objectives for SOCCR and CCSP SAP 2.2 are: (1) to summarize scientific knowledge about carbon cycle properties and changes, and (2) to provide scientific information for decision support and policy formulation concerning carbon. The report summarizes knowledge and uncertainties about the carbon cycle in Canada, the United States, and Mexico relevant to North America and the rest of the world. In a format useful to decision makers, it provides scientific information for decision support focused on key issues for carbon management and policy. The report addresses carbon emissions, natural carbon cycling on land and in coastal oceans, and options to manage emissions and carbon sequestration. The report is a community effort with more than 75 scientific authors for the U.S., Canada and Mexico and actively engaging a broad spectrum of decision makers through a series of workshops. We briefly summarize the near final content of the draft report and describe the project's experience with integrating scientific assessment and stakeholder interests

J.8: Decision Support Tools and Data Analysis for Ecosystem Carbon Management in the United States

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Ecosystem modeling and satellite remote sensing are being used in combination to assess activities such as land use change and afforestation on carbon pools and fluxes across the United States. An internet-based decision support tool called CASA-CQUEST (Carbon Query and Evaluation Support Tools), has been developed for carbon management in U. S. ecosystems. Using the NASA-CASA model for predictions of regrowth forest production, a conservative national projection of 0.3 Pg C is reported as potential carbon stored each year through afforestation on relatively low-production crop or rangeland areas. Afforestation at this level of intensity has the capacity to offset at least one-fifth of annual fossil fuel emission of carbon in the United States. These projected afforestation carbon gains also match or exceed recent estimates of the annual sink for atmospheric CO2 in currently forested area of the country.

J.9: Economic Potential for Carbon Sequestration through Afforestation of Agricultural Lands in the Northeast States

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Many estimates of carbon sequestration potential on the land tend to be of the technical potential, without consideration of current land values and alternate uses. The main goal of the work presented here is to estimate the quantity and associated costs of increasing the storage of carbon by afforestation of existing agricultural land in the 11 states of the Northeast United States. This study builds on previous analyses using a similar approach for other regions of the US including nine southern states and three western states. The focus of the work is to quantitatively describe where, how much, and at what cost in the region it would be economically attractive to shift agricultural production to afforestation to increase carbon storage on the land. Information about current land use, potential changes in land use and the incremental carbon resulting from the change, opportunity costs, conversion costs, annual maintenance costs, and measurement and monitoring costs were obtained and used in the analyses. The analyses are performed in a geographic information system (GIS) at the county scale of resolution to include the diversity of land uses, rates of carbon sequestration, and costs over three time periods of 10 years, 20 years and 40 years. Results indicate that the marginal cost of sequestering carbon on croplands was considerably higher than on pasture/hay land. For example, at a price of ≤$10/t CO2, about 28 million tons of CO2 could be sequestered after 40 years by afforestation of about 120 thousand hectares of existing pasture/hay lands in the NE states, but no cropland would be available at this price. If the price of carbon was up to $40/t CO2, then about 120 thousand t CO2 could be sequestered on about 640 ha existing cropland after 40 years. A similar analysis for the forest sector showed that extending rotation age by 5 year for softwood forests in the same region could sequester about 13 million t CO2 if the price was ≤$10/t CO2. However, in the present rules for terrestrial carbon offsets in the RGGI for the NE states, only afforestation is allowed, clearly missing the opportunity for significant quantities of low-cost offsets in the forest sector. This work demonstrates the need for such assessments as presented here before final decisions about which activities to include in mitigation programs are made.

J.10: Carbon Management in Intensively Managed Loblolly Pine Plantations

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We are using a systems engineering approach to integrate Earth science observations and predictions resulting from NASA research into an existing forest management decision support tool, LobDST. Our objective is to enable landowners to make informed decisions about thinning and fertilizing with full understanding of the resulting implications for carbon sequestration (ecosystem net carbon balance less embodied carbon costs of silvicultural prescriptions) and productivity. LobDST enables forest landowners to understand the effects of silvicultural prescriptions, particularly thinning and fertilization, on growth and yield - but currently has no output that would allow carbon to be managed concomitantly. It was developed by forest industry under the aegis of the Forest Nutrition Cooperative and Loblolly Pine Growth and Yield Research Cooperative, and is owned by the companies and organizations that comprise these two cooperatives. Current project activities include the following: (1) regionwide soil carbon dioxide effux sampling in thinned and/or fertilized stands, (2) adaptation of the NASA Carnegie-Ames-Stanford Approach (CASA) model for intensively managed plantations and (3) upscaling Landsat EVI to the temporal resolution of MODIS composite products to enable LUE-based modeling at the scale of forest management in the US Southeast.

Reconciling Top-Down and Bottom-Up Approaches to Estimating Carbon Fluxes

K.1: Top-down constraints on carbon dioxide surface fluxes with carbonyl sulfide observations

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Inversion studies combine carbon dioxide observations and atmospheric transport models to infer surface fluxes of carbon dioxide. The covariance between carbon dioxide and carbon monoxide has been shown to provide a powerful tool for improving the accuracy of these optimized fluxes. However, this approach is not as useful for studies during the growing season when the biosphere fluxes are in question. It has been hypothesized that carbonyl sulfide could provide a novel tracer for extracting information about carbon dioxide. Here we demonstrate how carbonyl sulfide observations can be exploited in a four dimensional variational data assimilation framework to obtain improved carbon dioxide surface flux estimates during the growing season over North America. We use aircraft observations from the NASA INTEX-A experiment along with the STEM regional atmospheric transport model. In the future, observations of carbonyl sulfide made along with carbon dioxide could provide a great benefit to unraveling the processes associated with carbon dioxide fluxes.

K.2: Landscape-level Carbon Flux Estimates from CO2 Concentration Measurements on Flux Towers and Remote Sensing-based Footprint Integration

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Carbon fluxes at the landscape level (~104 km2) are estimated using two independent methods: (1) retrieving daily gross primary productivity (GPP) and ecosystem respiration from the diurnal CO2 variation pattern (Chen et al., GRL, 33: L10803, 2006), and (2) spatially explicit hourly carbon cycle modeling based on remote sensing and then integrating the daily flux field with a concentration footprint function depending on wind and stability. Results from these two methods are compared against eddy covariance measurements representing a small area within the footprint. These comparisons so far have been made for a 28-m tower at an old black spruce site near White Swan Lake (~100 km NE of Prince Albert: 53.98717oN, 105.11779o W), Canada. Similar approaches are being used for three more towers in Canada and the Wisconsin tall tower at USA.

K.3: Using auxiliary environmental data to constrain global carbon fluxes within a geostatistical inverse modeling framework

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This poster presents global monthly CO_2 fluxes from 1997 to 2001 estimated at a 3.75°x5° resolution using a geostatistical inverse modeling (GIM) framework. Atmospheric concentration measurements from the global NOAA-ESRL Monitoring Network at 44 locations were used along with an atmospheric transport model to infer 3456 fluxes per month. GIM is a Bayesian approach that does not rely on prior estimates of flux to help constrain flux distributions. The approach instead relies on careful characterization of the autocorrelation of the flux distribution, and can select and use relevant auxiliary environmental datasets to determine a model of the trend flux distribution. Auxiliary datasets included in the analysis were Gross Domestic Product, Leaf Area Index, Fraction of Photosynthetically Active Radiation (fPAR), % Shrub Cover and Air Temperature over land. The drift coefficients representing the quantitative relationship between the auxiliary data and inferred fluxes were estimated simultaneously with the flux distributions, and can potentially be used to provide process-based understanding of flux drivers within biospheric models. The environmental datasets included in the inversion also help to reduce uncertainty and recover small-scale spatial and interannual variability in the flux estimates that cannot be inferred from the atmospheric data alone. A recently funded proposal within the NACP ("Constraining North American Fluxes of Carbon Dioxide and Inferring Their Spatiotemporal Covariances Through Assimilation of Remote Sensing and Atmospheric Data in a Geostatistical Framework") will apply the GIM approach to estimate CO_2 fluxes for the North American continent at a 1°x1° resolution. Lessons learned from the global GIM study about integrating top-down and bottom-up approaches to flux estimation will be valuable in applying this technique for North America.

K.4: Techniques in scaling ecosystem carbon flux from landscape studies to broad scale remote sensing.

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Utilization of broad scale remote sensing technologies for the detection of carbon uptake and storage patterns is a key focus area of the North American Carbon Program. In order to properly parameterize and interpret such remote sensing driven models, development and refinement of scaling techniques from focused ground measurements to high resolution remote sensing and ultimately to broad scale sensors is required. As part of a larger NACP initiative, advancements have been made in key techniques related to the scaling of ecosystem carbon dynamics. This presentation discusses several of these integrated field, modeling and remote sensing approaches in the context of their usefulness in meeting the scaling objectives of our NACP project.

Specific areas of discussion include: Site specific evaluation of an ecosystem model, driven by foliar nitrogen concentration, at a variety of flux sites across the United States. Progress in refining estimates from this model by employing a meteorology based tower footprint analysis to weight ecosystem model inputs. Derivation of horizontal and vertical canopy structural metrics from hemispherical photography which can be used to train and validate potential retrievals of similar variables from lidar and multi-view angle remote sensing independently of spectrally determined foliar chemistry.

K.5: Progress in Modeling Global Atmospheric CO2 Fluxes and Transport

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Progress in better determining CO2 sources and sinks will almost certainly rely on utilization of more extensive and intensive CO2 and related observations

including those from satellite remote sensing. Use of advanced data requires improved modeling and analysis capability. Under NASA Carbon Cycle Science support we seek to develop and integrate improved formulations for 1) atmospheric transport, 2) terrestrial uptake and release, 3) biomass and 4) fossil fuel burning, and 5) observational data analysis including inverse calculations. The transport modeling is based on meteorological data assimilation analysis from the Goddard Modeling and Assimilation Office. Use of assimilated met data enables model comparison to CO2 and other observations across a wide range of scales of variability. In this presentation we focus on the short end of the temporal variability spectrum: hourly to synoptic to seasonal. Using CO2 fluxes at varying temporal resolution from the SiB 2 and CASA biosphere models, we examine the model's ability to simulate CO2 variability in comparison to observations at different times, locations, and altitudes. We find that the model can resolve much of the variability in the observations, although there are limits imposed by vertical resolution of boundary layer processes. The influence of key process representations is inferred. The high degree of fidelity in these simulations leads us to anticipate incorporation of real-time, highly resolved observations into a multiscale carbon cycle analysis system that will begin to bridge the gap between top-down and bottom-up flux estimation, which is a primary focus of NACP.

K.6: Carbon Flux Super Site

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In a concentrated, integrated effort, this new study harnesses cutting-edge technologies to generate insights leading to highly relevant biological and physical process information about the carbon cycle. Novel measurements on carbon exchange in difficult conditions will result in more scientifically credible data. The data will be used as input into regional models and will enable more accurate simulations of climate change scenarios that result from increased atmospheric CO2 concentrations.
Using recent methods to characterize the impact of frequent and poorly documented atmospheric phenomena on carbon fluxes, this project leads to revised, more robust regional-scale carbon fluxes. These revised carbon flux estimates are then incorporated into a state-of-the-art modeling framework in order to improve our knowledge of atmosphere-terrestrial ecosystem exchange obtained using both stationary and airborne flux platforms combined with onsite tall tower CO2 mixing ratio measurements,. The present project makes full use of the advantages of the Savannah River Site which is characterized by an exceptionally well developed infrastructure, a rich repository of ecological, atmospheric, climatological/land use information, and highly qualified local personnel in one of the most biodiverse and carbon-rich regions of the US. With 48% of the net carbon uptake, this site is located in one of the most productive regions of the continental US; it is also characterized by a lack of carbon-atmosphere exchange data along the North Carolina-Florida corridor.
This project seeks 1. To validate a new, alternate method of measuring fluxes for conditions where eddy-covariance flux measurements are unreliable 2. To determine nocturnal atmospheric footprint and validation 3. To link anomalous atmospheric flow features such as waves/ wave-turbulence interactions to nighttime fluxes 4. To examine the importance of atmospheric low-level jets on vegetation fluxes 5. To provide a quantitative, spatially, and temporally resolved description of carbon, water, and energy exchange at the regional scale.

K.7: Fuel Loading and Consumption Models for Assessing Carbon Release from Wildland Fires

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Carbon released from wildland fires can be estimated from area burned, fuel loading, fuel consumption, and pollutant - specific emission factors. Two factors alone -- fuel loading and fuel consumption -- account for up to 80% of the error associated with estimating total carbon. We demonstrate ground-based estimates of these factors with two new software tools, the Fuel Characteristic Classification System (FCCS) and Consume 3.0.
The FCCS provides an exhaustive description of fuelbed layers, including canopy, shrubs, nonwoody, woody, litter/lichen/moss, and duff. FCCS fuelbeds represent the United States, including Alaska and Hawai'i, Canada, and a portion of Mexico. They were compiled from scientific literature, fuels photo series, fuels inventories, and expert opinion, and can be modified to represent fuel conditions at the scale of interest, from single plots to 1-km cells. Fuelbeds are mapped via crosswalks to satellite-derived vegetation and land cover. This has been completed at a 1-km scale for the continental United States and will be extended to include all of North America. Consume 3.0 is a user-friendly software application for estimating fuel consumption and emissions produced. It imports fuelbed data directly from the Fuel Characteristic Classification System (FCCS), and the output is formatted to feed other models and provide usable outputs for estimation of total emissions and carbon generated from wildland fire. Consume can be used for all forest, shrub, and grassland types in North America. These software tools can complement and validate remotely sensed estimates of fuel loadings, consumption, and carbon release.

K.8: Contribution of Ocean, Fossil Fuel, Land Biosphere and Biomass Burning Carbon Fluxes to Seasonal and Interannual Variability in Atmospheric CO2

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The seasonal and interannual variability in atmospheric carbon dioxide (CO_2) concentrations is simulated using best available estimates of surface carbon fluxes and a tracer transport model that incorporates interannual variability in transport. Ocean fluxes are based on physical and chemical forcings for the period 1979-2004 using the WHOI ocean ecosystem model. Land fluxes are based on the GFED terrestrial carbon model, which uses satellite observations to constrain net primary production and fire emissions for the period 1997-2004. Interannual estimates of direct anthropogenic carbon emissions are obtained from fossil fuel databases. The atmospheric CO_2 variability resulting from these surface fluxes is compared to observations from 89 GLOBALVIEW monitoring stations with the goal of assessing the relative importance of land and ocean fluxes for seasonal and interannual variability. At northern hemisphere stations, the model is generally able to capture the observed seasonal cycle in atmospheric CO_2, which is dominated by the land tracer. The ocean tracer tends to be out-of-phase with the observed seasonal cycle at these stations and its seasonal amplitude is only ~10%, on average, of the observed total cycle. Land also dominates interannual variability in atmospheric CO_2 in the northern hemisphere, and biomass burning in particular can account for much of the strong positive CO_2 growth anomaly observed during the 1997-1998 ENSO event. The signals in atmospheric CO_2 from northern land extend throughout the southern hemisphere, but oceanic fluxes also exert a strong influence there, accounting for roughly half of seasonal and interannual variability at southern monitoring stations.

K.9: Carbon cycle data assimilation to improve terrestrial carbon flux diagnosis and prediction

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Obtaining a coherent and complete understanding of the terrestrial carbon cycle of North America requires the integration of multiple sources of data including atmospheric mixing ratio measurements, flux tower observations, ground-based carbon inventories, and space-based remote sensing. Central to successful integration of such data is an understanding of the spatial and temporal scales, and ecosystem functions that are captured by these observations. Further, numerical models that effectively capture the essential ecosystem functions and their response to environmental drivers are needed to interpolate observations across space and time, and to make predictions of the response of the terrestrial carbon cycle to future climatic change.
Towards this end we have initiated a program of carbon cycle data assimilation, focused initially on the assimilation and eventual integration of flux tower and atmospheric mixing ratio measurements at regional, continental and global scales. This poster will focus on progress in flux tower data assimilation at regional and continental scales, including results including parameter estimation, model evaluation, and space-time coherence in flux tower observations. We will also outline progress, plans and pending questions concerning the effective integration of flux tower data with atmospheric mixing ratio data, and will contrast work using global models more suitable for predictive applications with regional to continental diagnostic applications. Finally, we will review initial attempts towards assimilation of ground-based carbon inventory data and land use history in a regional assimilation experiment.

K.10: Uncertainty estimates for prognostic modeling of terrestrial carbon cycle at continental to global scales.

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We demonstrate the use of multiple observational datasets to quantify uncertainty in forward (prognostic) model estimates of various quantities associated with terrestrial carbon cycling. The modeling framework used here is the Community Land Model with coupled Carbon-Nitrogen cycles (CLM-CN), a component of the NCAR Community Climate System Model (CCSM). Datasets include global syntheses of in situ net primary production and biomass measurements, remote sensing measurements of net primary production and leaf area index, and eddy flux measurements of energy, water, and carbon fluxes at multiple sites. We show how the uncertainty estimates produced by evaluating forward model predictions against observations can be used in conjunction with error estimates from inverse modeling methods to identify regions and/or processes which require more focused investigation.

K.11: Regional Flux Intercomparison in the Southern Great Plains during the 2007 NACP Mid Continent Intensive: an invitation to participate

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In June 2007, an intensive regional campaign will take place in the Southern Great Plains to estimate land-atmosphere exchanges of CO2, water, and energy at 1 to 100 km scales. Primary goals of this North American Carbon Program (NACP) campaign are to evaluate top-down and bottom-up estimates of regional fluxes and to understand the influence of land cover, moisture gradients, and atmospheric transport on fluxes and their estimation. Centered in Oklahoma and Kansas, this experiment will characterize regional fluxes and incoming air masses at the southern boundary of the Mid-Continent Intensive region.
The work will be integrated with the Cloud and Land Surface Interaction Campaign (CLASIC) on land surface-convective boundary layer-cumulus cloud interactions, which will utilize an array of atmospheric measurements. All data streams will be available to interested researchers.
We invite regional flux modelers to participate in an intercomparison of top-down and bottom-up methods of regional flux estimation, taking advantage of these uniquely coherent and complete data sets. Eddy flux towers will be deployed in the four major land cover types. In addition, CO2, water, and energy fluxes will be observed with the Duke Helicopter Observation Platform (HOP) in the boundary layer, including the surface layer. Continuous CO2, CO, and radon concentrations will be measured and NOAA-ESRL flasks collected from a centrally located 60 m tower. Aircraft will have continuous CO2, CO, and radon systems, and 14C and NOAA-ESRL 12-flask packages. Flights are planned to constrain boundary layer budgets and air mass following experiments. Distributed surface fluxes will be modeled run off-line and coupled to MM5; surface and met data (including a soil moisture product from the ER-2) will be available to run other land surface models. Contact us or see www.ARM.gov or http://esd.lbl.gov/ARMCarbon/.

K.12: New constraints on Northern Hemisphere growing season net flux

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Observations of the column-averaged dry molar mixing ratio of CO2 above both Park Falls, Wisconsin and Kitt Peak, Arizona, together with partial columns derived from six aircraft profiles over Eurasia and North America are used to estimate the Net Ecosystem Exchange (NEE) between the atmosphere and the terrestrial biosphere in the Northern Hemisphere. We find that NEE is approximately 25% larger than predicted by the Carnegie Ames Stanford Approach (CASA) model. We show that the earlier estimates of NEE based on surface CO2 observations alone were biased low by the overly sluggish vertical exchange in the transport models. To the extent that this transport error also underestimates the rate of mixing of the fossil fuel carbon into the free troposphere, the inter-hemispheric gradient in the atmospheric CO2 mass is also likely underestimated in the previous TransCom studies. If so, the uptake of anthropogenic carbon in the Northern Hemisphere is smaller than previous estimates.

K.13: Tropospheric CO interannual variations: a way to estimate gaseous emissions from boreal forest fires.

Leonid Yurganov, JCET/UMBC, yurganov@umbc.edu (Presenting)
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Carbon dioxide is the main part of biomass burning gaseous emissions. Carbon monoxide (CO) is the second one and its interannual variations amounting to 40-60% of background values easily can be measured and used to estimate CO2 emissions. This report presents results of consistent grounds-based remote sensing of CO since 1996 until the end of 2006 compared with satellite data since 2000. Boreal forest/peat fires in the Northern Hemisphere occur in spring and summer every year and are spreading into early autumn. However, the severity of these fires varies significantly from year to year. The fire seasons of 2002 and 2003 with record intense Siberian fires were followed by record North American fires in 2004 and moderate fires in 2005 both in North America and Eurasia. The most recent tropospheric CO data obtained in 2006 show significant CO fire emission events both in North America and Eurasia. Nevertheless, ground-based spectroscopic measurements in the United States and Russia, in agreement with satellite global MOPITT and AIRS observations, rank 2006 as a year of moderate fire emissions. The record fire emissions of 1998 and 2003 are not yet beaten.

K.14: Maximum Likelihood Ensemble Filter (MLEF) approach to carbon data assimilation

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Ensemble based data assimilation techniques are promising for many applications in geosciences because of their capability to estimate analysis and forecast uncertainties consistent with the model dynamics. The ensemble-based methods are especially attractive for carbon transport inversion problems involving complex atmosphere-hydrology-biosphere coupled models because of their computational efficiency (compared to computationally more demanding Kalman filter methods).
Some of the challenging issues that are still not adequately addressed within the ensemble based data assimilation methods include model error estimation and covariance localization. In this presentation we explain how these issues could be addressed within the Maximum Likelihood Ensemble Filter (MLEF), an ensemble based data assimilation technique currently being investigated for applications to carbon data assimilation problems of North American Carbon Program (NACP). We also provide a basic theoretical framework of the MLEF and demonstrate that, for linear problems involving Gaussian errors, the MLEF converges to the theoretically optimal results, obtained using the Kalman filter approach.

Integrating Social Science and Economics into NACP

L.1: Spatial Distribution and Density of Constructed Impervious Surface Areas in North America

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The construction and maintenance of impervious surfaces (buildings, roads, parking lots, roofs, etc.) constitutes a major human alteration of the land surface. The same characteristics that make impervious surfaces ideal for use in construction produce a series of effects on the environment. Impervious surfaces alter sensible and latent heat fluxes, causing urban heat islands. In heavily vegetated areas the proliferation of ISA reduces the sequestration of carbon from the atmosphere. ISA alters the character of watersheds by increasing the frequency and magnitude of surface runoff pulses. Watershed effects of ISA begin to be detectable once 10% of the surface is covered by impervious surfaces, altering the shape of stream channels, raising water temperatures, and sweeping urban pollutants into aquatic environments.
We have used two types of global coverage data to model the spatial distribution and density of impervious surface area (ISA) for the 2000-2001 time period at 30 arc second resolution. Input data include radiance calibrated nighttime lights and population count. The ISA model was calibrated using eighty aerial photographs selected on urban-to-rural transects from thirteen cities in the USA.
The resulting grid is available at http://www.ngdc.noaa.gov/dmsp/download.html. The grid should be useful for NACP investigators interested in quantifying human impacts on the terrestrial carbon dynamics of North America.

Data Systems/Management

M.1: NACP Data Center for Modeling and Synthesis

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The North American Carbon Program (NACP) is designed to quantify the magnitudes and distributions of carbon sources and sinks, explain the processes controlling them, and produce a consistent analysis of North America's carbon budget. To accomplish these ambitious goals, NACP requires an integrated data and information management system that will enable researchers to access, understand, use, and analyze large volumes of diverse data at multiple thematic, temporal, and spatial scales.

The Modeling and Synthesis Thematic Data Center (MAST-DC) is an integral component of the NACP data system and will support NACP by providing data products and data management services needed for modeling and synthesis. The overall objective of MAST-DC is to provide advanced data management support to NACP investigators and agencies performing modeling and synthesis activities. Based on specific requirements established by NACP, we will provide data products for modeling and synthesis in consistent and uniform grids, projections, and formats.

The specific tasks of MAST-DC are (1) coordinate data management activities with NACP modelers and synthesis groups; (2) prepare and distribute model input data; (3) provide data management support for model outputs; (4) provide tools for accessing, subsetting and visualization; (5) provide data packages to evaluate model output; and (6) support synthesis activities, including data support for workshops. MAST-DC will provide data products and services required by NACP in a central location, with common and co-registered spatial projection, in easily converted formats.

The MAST-DC will free modelers and those doing the synthesis and integration from having to perform data management functions. Consequently the MAST-DC will enable NACP participants to conduct their work more readily, facilitate the development of new model products needed by models, and assist in gaining new insights into the carbon cycle in North America.

M.2: Enhancing Linkages Between Projects and Datasets: Examples from LBA-ECO for NACP

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The Carbon Cycle and Ecosystems Office is developing ideas to build a warehouse of metadata resulting from the North American Carbon Program. The resulting warehouse and applications would be very similar to those developed for the LBA-ECO Project (www.lbaeco.org). The harvested metadata would be used to create dynamically generated reports, available at www.nacarbon.org, which would facilitate access to NACP datasets.

Our primary goal is to, as much as possible, associate harvested metadata with its corresponding project group profile. This also addresses high-priority goal #4 of the NACP Data System Task Force to "link the dataset metadata index with the project metadata index generated and maintained by the NACP Office"[1]. The benefit of achieving this goal will be the maximization of data discovery by association of each dataset with its corresponding NACP project group profile. This provides a greater understanding of the scientific and social context of each dataset. This will be challenging, because the datasets exist in many different formats, residing in many thematic data centers and also distributed among hundreds of investigators. Among other things, this situation creates a lack of consistency in how associated metadata is composed, thereby limiting our ability to fully automate metadata harvesting as well as dynamic generation of a wide variety of associated reports.

Our presentation will give a brief technical overview of how we plan to harvest the metadata. We currently only harvest metadata that is in an XML format. However, not all NACP datasets have corresponding metadata in XML. Therefore, we will need to expand upon our current capabilities by creating harvest and ingest scripts that can extract metadata in other formats.

We will also demonstrate what we can do for NACP by looking at what we have already done for LBA-ECO. For example, the LBA-ECO website (www.lbaeco.org) provides a profile (e.g. participants, abstract(s), study sites, and publications) for each LBA-ECO investigation. These profiles are very similar to the NACP project profiles. Linked from each profile is a list of associated registered dataset titles, each of which link to a dataset profile that describes the metadata in a user-friendly way. Moreover, each dataset profile contains hyperlinks to each associated data file at its home data repository and to publications that have used the dataset.

We also use the harvested metadata from the LBA Project in administrative applications to assist quality assurance efforts. These include processes to check for broken hyperlinks to data files, automated emails that inform our administrators when critical metadata fields are updated, dynamically generated reports of metadata records that link to datasets with questionable file formats, and dynamically generated region/site coordinate quality assurance reports. These applications are as important as those that facilitate access to information because they help ensure a high standard of quality for the information. Where possible, we hope to create similar reports for NACP.

[1] *Prioritized list of recommendations to CCIWG regarding NACP Data Central, NACP Data System Task Force, July 24, 2006.*

M.3: NACP Project Profiles: Enhancing communication among scientists and agency managers

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The NACP website provides a profile for each core and affiliated NACP project. This profile includes information such as the project's title, participants, an abstract, keywords, funding agencies, associated intensive field campaigns, and URLs to associated data centers, datasets, and metadata. By making this information easily and publicly available on our website, the NACP Project profiles become an important means of communicating the following to the larger carbon cycle science community:

1. Who are the NACP core and affiliated projects.
2. What specifically are these projects doing for NACP.
3. Who is participating in the projects.

To facilitate the creation and maintenance of accurate information, this presentation will step project leads through the process of submitting and updating an NACP project profile. It will discuss the various tasks that can be accomplished with the NACP Project Profile update tool. It will also discuss in detail the information that is displayed in the project profiles. Additionally, we will discuss future plans for profile search tools, answer questions about the submission process, and solicit feedback for additions and improvements to our existing profile infrastructure.

Thursday, January 25

Atmospheric Measurements and Analyses

A.2: Measuring CO_2 Fluxes from Space: The NASA Orbiting Carbon Observatory (OCO)

David Crisp, Jet Propulsion Laboratory, California Institute of Technology, David.Crisp@jpl.nasa.gov (Presenting)

The Orbiting Carbon Observatory (OCO) will make global, space-based measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize CO_2 sources and sinks on regional scales and quantify their vari¬ability over the seasonal cycle. This NASA Earth System Science Pathfinder (ESSP) mission will be launched from Vandenberg Air Force Base in late 2008. It will fly in a 705 km altitude, sun-synchronous (1:26 PM) near polar orbit (98.2 degree inclination) that provides global coverage of the sunlit hemisphere with a 16-day round track repeat cycle. OCO carries a single instrument, which incorporates 3 high resolution grating spectrometers that will make coincident measurements of reflected sunlight in near-infrared CO_2 and molecular oxygen (O_2) bands. These measurements will be analyzed with a remote sensing retrieval algorithm to provide spatially resolved estimates of the column-averaged CO_2 dry air mole fraction, XCO_2. The instrument collects 200 to 400 soundings per degree of latitude over the sunlit portion of the orbit. After screening for clouds and aerosols, the remaining data is expected to yield XCO_2 estimates with accuracies of ~0.3 to 0.5% (1 to 2 ppm) on regional scales every month. These measurements will be analyzed with source/sink inversion and data assimilation models to infer CO_2 surface fluxes. These results are expected to improve our understanding of the nature and processes that regulate atmospheric CO_2 enabling more reliable forecasts of CO_2 buildup and its impact on climate change.

A.12: Estimating local, regional and continental fluxes from the NOAA/ESRL aircraft networ

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Using a combination of vertical profiles made at 19 aircraft sites over the last 10 years and recent inversion results which assimilates the NOAA boundary layer flask network we explore the feasibility of estimating local, regional and continental fluxes from the NOAA/ESRL Global Monitoring Division (GMD) Aircraft Network. Three approaches for estimating fluxes are explored using aircraft profiles: 1) local eddy covariance using deviation in horizontal velocity and CO_2 from the free tropospheric mean to estimate outgoing fluxes at the "downwind" edge of the continental boundaries; 2) inversion techniques which utilizes a Lagrangian dispersion model to estimate fluxes from source regions of individual aircraft measurements; 3) a mass balance approach which calculates net surface fluxes by combining a geostatistical interpolation of vertical profiles with climatological winds. The mass balance approach estimates net surface fluxes as the monthly change in the CO_2 inventory minus the net monthly vertical and horizontal transport of CO_2 at the continental boundaries. Daily fields from the inversion results will be used to test how much information is lost with each flux estimating technique using vertical profiles made at bi-monthly time intervals.

A.15: A Nested Global Inversion System With a Focus on North America: Comparison With 1992-2003 Bottom-up Results in Canada

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Based on the TransCom inverse modeling for 22 global regions, we have developed a nested global inversion system for estimating carbon fluxes over 30 regions in North America (2 of the 22 regions are divided into 30). Irregular boundaries of these 30 regions are delineated based partially on ecosystem types and partially on provincial/state borders, so that the major ecosystems in North America are separated. Synthesis Bayesian inverse calculation is conducted on monthly time steps from 1992 to 2003 using CO2 concentration measurements at 88 coastal and continental stations located over the globe (GlobalView database). Responses of these stations to carbon fluxes from the 50 regions are simulated using the transport model from the National Institute of Environmental Studies (NIES) of Japan driven by the National Center for Environmental Prediction (NCEP)

meteorology. Terrestrial carbon flux fields used as a priori to constrain the inversion are obtained from Biome-BGC. The inversion results show that the terrestrial carbon sink in North America varied in the range from 0.534 to 1.112 ± 0.20 Pg C/y during the 1992-2003 period, with Canada showing a sink in the range from 0.004 to 0.313 ± 0.15 Pg C/y. Bottom-up modeling for Canada's forests and wetlands over the 1901-2003 period has been carried out using the Integrated Terrestrial Ecosystem Carbon Cycle Model (InTEC), which integrates disturbance and non-disturbance (climate, nitrogen, CO2) effects on the carbon cycle. Bottom-up results show that the sink in Canada's forests and wetlands varied from -0.045 to 0.165 Pg C/y.

A.16: Mesoscale Carbon Data Assimilation for NACP

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We are developing a generalized framework for flux estimation from multiple streams of carbon observations, including spectral vegetation and land cover imagery, eddy covariance flux observations, meteorological data, and both in-situ and remotely sensed observations of atmospheric carbon gases. We us Ensemble Data Assimilation (EnsDA) techniques applied to a coupled model of regional meteorology, ecosystem carbon fluxes, and biomass burning (SiB-CASA-RAMS). Terrestrial carbon fluxes over North America due to photosynthesis, autotrophic respiration, decomposition, and fires, and a "residual" time-mean source or sink will be simulated by the model. The EnsDA method does not require the development of an adjoint of the coupled model, but rather applies an optimization method that involves a large ensemble of forward simulations. Unlike previous high-resolution inversions using transport model adjoint methods, we will not assume surface fluxes remain constant on monthly time scales, nor do we treat the transport model as "perfect." Parameters in the forward coupled model are estimated.

We present preliminary results using the SiB-RAMS model, including a prototype of the EnsDA system using a greatly simplified version of the transport based on a Lagrangian Particle Dispersion Model (LPDM). Tests using synthetic data allow us to evaluate assumptions about the spatial and temporal covariance of forward model error. Temporal decomposition of CO2 fluxes into high-frequency physiological and slower biogeochemical mechanisms allow much better data constraint. We are also experimenting with optimization of boundary-layer mixing in the transport model.

A.17: An evaluation of the uncertainties of CO2 and sensible heat flux measurements from a light aircraft platform and comparison to tower-based measurements

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Fluxes of CO_2 and sensible heat were observed over the Ameriflux site in Pellston, Michigan using a twin-engine Beechcraft Duchess aircraft. Flux measurements were conducted during a series of flight legs approximately 5km in length from 150m above a predominately deciduous forest during the middle of the growing season between June 21 and July 24, 2006. A combination of a 9-hole wind probe, extending from the nose of the aircraft, and a GPS/INS system enabled measurement of the 3-dimensional winds at 50Hz. Dry Mole Fractions of CO_2 were sampled at 8Hz by an NDIR analyzer with negligible sensitivity to aircraft motion. Sensible heat fluxes were measured using a fast, ultra-sensitive thermocouple just below the wind probe. Measurements were conducted at multiple heights over an Ameriflux tower using racetrack and grid patterns to evaluate flux divergence. Fluxes were calculated by eddy covariance of 2Hz data and averaged over sets of flight legs. Analysis of power spectra and cospectra of the wind components and temperature show the predicted inertial subrange energy dissipation at higher frequencies. A propagation of the random and systematic errors of the measurements gives an overall uncertainty of the CO_2 and sensible heat fluxes. We present an evaluation of the sources of errors and the extent to which reliable flux measurements can be made from the piloted airborne platform. The aircraft fluxes are then compared to 30min averaged CO_2 and sensible heat fluxes at the top of the 46m Ameriflux tower. In addition to any random and systematic errors caused by limitations of the instrumentation, differences in flux measurements are assessed based, in part, on vertical flux divergence, nonstationarity, inhomogeneity, and differences in the footprint of the airborne and stationary platforms.

A.18: Airborne CO2 Flux Measurement at the National Research Council of Canada

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The Flight Research Laboratory (FRL) of the National Research Council, Canada (NRC) operates a fleet of eight research aircraft, both fixed and rotary wing. Of these aircraft, the Convair-580 and the DHC-6 Twin Otter aircraft are used primarily for atmospheric research flights. In addition, a third aircraft, a CT-133, is currently in the process of being re-instrumented and developed into a facility for high altitude atmospheric research.
This poster presentation will describe the capabilities developed over the years at NRC, in airborne flux measurement of CO2 and other trace GHG. Of the three NRC atmospheric research aircraft, the Twin Otter is used primarily as a low-altitude (0-10K') flux measurement aircraft, whilst the Convair 580 can cover the middle altitudes (10-25 K'). When instrumentation is complete, the CT-133 will be applied to the higher altitudes (25-40 K'), thus providing NRC the unique capability to conduct airborne measurement of atmospheric pollution, carbon fluxes and transport, up to altitudes of 40,000 feet. In particular, the CT-133 will be equipped with an Lii200 laser sensor for airborne black carbon measurements throughout the troposphere and tropopause, for a variety of research studies, including aircraft emissions, boreal forest fires, urban and industrial environments.
The presentation will focus primarily on the Twin Otter airborne flux facility (for CO2, CH4, H2O, O3 N2O), developed jointly with Agriculture and Agri-Food Canada. It will also include descriptions of the other two airborne facilities, in terms of sensors on board, the methodology of measurement, accuracy/resolution achieved and impact of these measurements.

A.19: Ground- and space-based spectrometers for monitoring biomass burning emissions

Leonid Yurganov, JCET/UMBC, Baltimore, MD, Yurganov@umbc.edu (Presenting) , **Wallace McMillan**, UMBC/JCET, Baltimore, MD, McMillan@umbc.edu

Carbonaceous gases (CO2, CH4, and CO) are important components of gaseous emissions from forest fires. All these gases have spectral features in the atmospheric emission spectrum and can be retrieved using fast codes. This report presents technique particulars and results of CO measurements from the ground (Great Southern Plains ARM site in Oklahoma) and CO retrievals from the Atmospheric InfraRed Sounder (AIRS) instrument onboard the Aqua satellite. The most recent results obtained in 2006 demonstrate several events of strong boreal forest fires and long-range transport from North American and Eurasian sources. We are developing CO2 and CH4 retrievals for our ground-based thermal emission instruments and will compare results to available in situ and satellite retrievals of these gases.

Terrestrial and Riverine Measurements and Inventories, including Flux Measurements

B.3: Mapping Carbon Pools in the Southwestern US

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Active technologies (radar and lidar) are proving promising for remotely inventorying aboveground biomass although these methods are not yet able to acquire data at regular intervals over large areas. An alternative and complementary approach is the use of multi-angle imaging; here, data from the NASA Multi-angle Imaging Spectro-Radiometer (MISR) on the Earth Observing System Terra satellite were used to estimate the fractional cover and mean canopy height of woody plant canopies; and to map aboveground biomass for parts of Arizona and New Mexico (>200,000 km^2). Red band bidirectional reflectance estimates in nine views mapped to a 250 m grid were used to adjust the Simple Geometric-optical Model (SGM). The soil/understory background signal was decoupled a priori by exploiting relationships with the nadir camera blue, green, and near-infrared reflectance data and the kernel weights of a bidirectional reflectance distribution function (BRDF) model. The SGM was adjusted using the Praxis optimization algorithm. Some areas with shrub cover were predicted to have no woody plant cover, reflecting the difficulty of estimating canopy parameters in low cover environments. Retrieved distributions for forested areas showed good matches with data extracted from US Forest Service maps, with R^2 values of 0.76, 0.58 and 0.53 after filtering for high root mean square error and cloud/cloud-shadow contamination. This is the first attempt to use data from MISR to produce maps of crown cover, canopy height, and aboveground biomass over a large area.

B.5: Modeling variability in biomass consumption for estimating fire emissions

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The study presented focuses on quantification of the variability in fuel consumption for the purpose of estimating carbon emissions during biomass burning. Landsat multi-spectral images are used to determine how much of the landscape is affected by fires of low, moderate, or severe consumption level within 13 forested ecoregions. Field-based measurements of fuel consumption are used to associate the remote sensing-based map of consumption level to the amount of fuel consumed (kg/m2). Fuel consumption in forested ecoregions of western and northern North America where forest fires are prevalent is the region of interest. In this presentation, the approach for mapping and measuring fuel consumption using a combination of remote sensing-based land classification and field measurements is described. Because data available for the boreal and temperate study regions are not the same, different approaches are used in Alaska, Canada, and the western lower-48 study regions. Preliminary results of mapping fuel consumption in Alaska shows a small percentage of the land burns in severe fires, but since this represents a substantial amount of the total carbon emissions, increases in severe fire will result in more extreme emissions events. Results of a model-based assessment of consumption in western lower-48 forested regions provides a quantitative review of the impact of fire on carbon emissions not previously available. Analysis of data provided by the Canadian Forest Service shows high levels of variability in fuel consumption in boreal North America and an uncertainty not yet quantified related to burning of boreal peatlands.

B.19: Carbon Cycling in Mature and Harvested Black Spruce Forests in Eastern Canada

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Ecosystem-level carbon (C) fluxes were measured from June 2003 to December 2005 over a mature boreal black spruce forest and from January 2003 to December 2005 over a black spruce cutover site located near Chibougamau, Québec. An operational scarification treatment was applied at the end of October 2003 at the harvested site while the mature stand structure was not disturbed during the study period.
In 2004 and 2005, the mature stand was C neutral (Net Ecosystem Productivity (NEP) = 0 - 6 g C m-2 y-1) while the harvested site was a strong C source of 167 to 119 g C m-2 y-1 from 2003 to 2005. Sensitivity of total annual Gross Ecosystem Productivity (GEP) and ecosystem respiration (R) to variable environmental conditions was high at both sites. The variability in the annual C budget of the sites was mostly determined by the timing of the beginning of the growing season at the mature site and by mid-summer temperatures at the cutover site
Light, air temperature and vapor pressure deficit (VPD) affected GEP at both sites. High air temperature and VPD had a stronger limiting effect on GEP at the mature site.

B.21: Quantifying the carbon budget of developed land use in North America

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The rate at which wildlands and croplands are being developed for human settlement in the United States currently exceeds population growth by a factor of two to four. Developed land areas represent major sources of CO_2 and other radiatively-important trace gases due to the concentration of human activities that consume fossil fuels. However, they are also ecosystems with significant vegetation covers that take up CO_2 and soils that release CO_2. Direct measurements are needed to quantify the land-based sources and sinks of CO_2 in developed areas, especially residential developed land, which accounts for most of the land-use change. We are quantifying the components of CO_2 exchange in a first-ring suburb of Minneapolis-St. Paul, Minnesota, using tracer measurements, traffic and energy-use monitoring, and time-series analyses. Second, we are determining the controls on biotic fluxes from measurements of a suite of biophysical properties measured for each surface or plant functional type (PFT; deciduous and evergreen trees, turfgrass, bare soil, and impervious or constructed). And third, we are developing algorithms for each PFT to estimate component CO_2 fluxes from remotely-sensed data. Biophysical properties and PFTs are mapped using multi-resolution satellite imagery (QuickBird, 2.4-m, and Landsat TM/ETM+, 30-m pixel) and linear mixing models. Currently, a flux time series of >1 year has been produced and initial parameterizations of a production efficiency model (PEM) driven by absorbed photosynthetically-active radiation (APAR) and a soil respiration model driven by temperature (air and land surface temperature) have been developed.

B.24: Trends in CO2 Exchange at Harvard Forest

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We have been observing CO_2 fluxes , biomass, and meteorology from a mixed deciduous forest in central Massachusetts. Annual carbon fluxes at this site are quite variable, but significant trends are evident in the long-term record; magnitudes of both photosynthetic uptake (GEE) and ecosystem Respiration (R) were increasing (11.1 + 0.36 y^{-1} and 9.82 + .22 y^{-1} Mg-C $ha^{-1}y^{-1}$ since 1990, respectively). Because GEE is increasing faster than R, the overall magnitude of net ecosystem exchange (NEE) has been increasing (1.28 + 0.15 y^{-1} Mg-C $ha^{-1}y^{-1}$ since 1990). The increasing uptake rate is unexpected for this 75-110 year old forest. There were parallel increases in mid-summer photosynthetic capacity at high light level (21.5 - 31.5 µmole $m^{-2}s^{-1}$), woody biomass (101 - 115 Mg-C ha^{-1} from 1993-2005, mostly due to growth of one species, red oak), total leaf area index (4 - 5.5 from 1998-2005), and a slight increase in coarse woody debris (CWD). The long term trends were interrupted in 1998 by sharp declines in photosynthetic capacity, NEE, and other parameters, with recovery over the next 3 years. Episodic mortality events contribute varying inputs to CWD. Tree-ring analysis of 20 regional cut and uncut red oak populations indicates that tree-level average annual carbon increment is increasing rather than decreasing with stand age. These findings suggest that the increasing uptake rate at the HF may be a more general feature of red oak forests across the region.

B.41: Carbon stocks in primary and secondary tropical forests of Mexico

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We provide a synthesis on site-level information, published and unpublished, on carbon stocks of moist and dry tropical forests of Mexico. We also include data on C stocks in secondary tropical forests. Aboveground C stocks range between 22-59 Mg/ha in the western region of Mexico and between 61-73 Mg/ha in the Yucatán peninsula. Total ecosystem C stocks are 142 Mg/ha in dry and 307 Mg/ha in floodplain forests in the tropical dry region of Chamela. C stocks in moist forests amount to 414 Mg/ha in Los Tuxtlas, Veracruz and 452 Mg/ha in the Lacandona of Chiapas. Carbon stocks in secondary forests vary with age and represent varying proportions of those in primary forest. Soil C may represent up to 100% and aboveground C at most 74% of the C stocks in primary forest. Site-level information of C stocks in mexican tropical forests is still scarce and efforts are needed to provide more comprehensive estimates.

B.42: Opportunities for carbon sequestration and conservation in semiarid rangelands and grazing lands over the Mexico - USA border

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The border region between Mexico and the United States is characterized by large areas covered by diverse types of semiarid vegetation, mostly represented by grasslands and shrublands. It is thought that these ecosystems play a fundamental role on the regulation of carbon fluxes at local level, with a significant impact at a global scale. However, mismanagement through overgrazing, selective logging and unplanned changes in land use is changing the role of these lands from sinks to sources of carbon. The regional impacts of productive activities on local carbon budgets are poorly documented or in any case unknown. These situations offer varied opportunities for carbon sequestration in these areas through appropriate management and ecological restoration.
Chief opportunities to improve carbon sequestration in those ecosystems should include: assessments of the potential of soils and present vegetation to capture carbon; projection of carbon stocks for current and improved scenarios under current land uses; designing of soil and plant restoration strategies for such uses, and initiatives for joint collaborations along the border.
An alliance between two work groups located nearby both sides of the international border is recently taking place. This joint initiative is represented by universities, research centers, private industries, NGO's and government agencies. Its focus is mostly on technologies for ecological restoration of border degraded rangelands, therefore an added value for carbon sequestration is strongly implicit. Such opportunity should encourage NACP international groups to joint other groups' efforts with common interests for understanding and improving the carbon cycle in key regions, such as the Mexico-USA border.

B.43: Long-wavelength flux contributions as reason for the underestimation of conventional tower-based eddy-covariance measurements

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A lack of energy balance closure is found as general phenomenon for direct surface flux measurements, which are often used to estimate net ecosystem exchange rates of CO2. Recent experimental and model studies suggest that the primary reason for this problem is the underestimation of eddy-covariance measurements with a single tower set-up, which commonly use averaging times between 30 and 60 minutes. It is shown that the energy balance can be closed for specific sites when the averaging time is extended to several

hours. Aircraft measurements are used to investigate those mesoscale flux contributions that cannot be detected by conventional tower measurements. The results of a wavelet analysis of 20 flights over heterogeneous terrain in a boreal ecosystem indicate that mesoscale fluxes were of comparable magnitude as the energy balance residuals from single tower measurements close to the flight track. This analysis provides an experimental evidence for transport mechanisms that were described in previous generalized LES model studies. Based on this better understanding about the reasons for the flux underestimation potential approaches are given to deal with this problem.

B.44: Carbon stocks and emissions dynamics, derived from land use change process in the Highlands in Central Mexico, for 1986-2000.

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This study intends to estimate, carbon content in aboveground biomass (AB) litter and soil in ten different land cover-land use classes (LC/LU) in the Highlands in Central Mexico, to understand carbon losses and dynamics by stock and by land conversion process, as a consequence of the human activities influence to increase carbon dioxide concentrations in the atmosphere, and its impact in global climate change.
Total carbon estimated in this research, register an interval from 82.7 to 266.9 MgC/ha; based on a detailed analysis of the process of land use change within the Region, we estimate that a total of 10.37 TgC were emitted within the Region in a 14 yr period, and the carbon sequestration reached 10.36 TgC, mostly because as a result of the abandonment of agricultural lands and the recovering of secondary forest. The net carbon flow (emission minus sequestration) in the reached was 14.9 GgC.

B.45: Modelling the Impacts of Reservoirs and Forest Harvesting on the Carbon Budget of Aquatic Ecosystems in Quebec, Canada

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Aquatic ecosystems play a key role in the fate of terrigenous organic matter (TOM). The understanding of the role of aquatic ecosystems in processing TOM is hampered by several uncertainties regarding the relations between terrestrial and aquatic ecosystems. Consequently, it is presently difficult to adequately evaluate the impacts of anthropogenic disturbances on the greenhouse gas (GHG) budgets of watersheds. In this study, we aim at developing a better understanding of the respective impacts of reservoirs and forest harvesting on the aquatic fate of TOM, in order to estimate the resulting changes in GHG emissions budget at the watershed scale. We will present the development of a new process-based model (Integrated Carbon Cycle Model - ICC model) capable of integrating (1) fine biogeochemical proxies with respect to the carbon dynamics in lakes and perturbed aquatic ecosystems such as human-made reservoirs as well as (2) modifications in TOM exports due to forest harvesting. The ICC model will be developed through two iterative and complementary components: a modeling approach and an empirical biogeochemical approach. The challenges for coupling terrestrial ecosystem models with aquatic ecosystem models will also be discussed.

B.46: Response of surface fluxes at a Tropical Deciduous Forest site in northern Mexico to the North American Monsoon (NAM)system.

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The tropical deciduous forest (TDF) is an important biome that is present is present in North America as far north as central Sonora in Mexico. A site was established near Tesopaco, Sonora in the summer of 2004 as one of several surface flux sites during the NAM Experiment (NAME) of that summer. The data captured at this site in 2004 showed the largest and most rapid increases in Vegetation Index and EvapoTranspiration ET of any of the sites in the region. (Rather surpringly, the broad band albedo is almost constant.) It was also observed that the a higher fraction of available energy is used in ET for the TDF but that the fraction of rainfall used in ET is mech less that for vegetation in drier more desert environments.
This site has been operated continuously since July 2004 and results will be presented from the past 3 years for the changes in surface fluxes of radiation, heat, water vapor and carbon dioxide that occur as the NAM develops.

B.47: Novel Non-Destructive Soil Carbon Analysis; II - Characteristics and Results

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Inelastic Neutron Scattering (INS) system for soil carbon measurement can be briefly described as a gamma ray spectroscopy induced by fast, 14 MeV, neutrons that interact with

the nuclei of the elements present in the soil matrix. The INS system is non-destructive in which the neutron generator with the detection system are mounted on a cart about 30 cm above the ground. The system is operated in either stationary or scanning mode when towed over the field it provides a true mean value over the scanned area. The scanning is performed at typical speeds of 5 miles per hour although, depending on the surface roughness, can be moved at higher speeds. The volume probed by the system is several hundreds of kilogram depending on the soil bulk density and moisture. At present the INS system has been calibrated to measure carbon and it is planned to calibrate it to measure at the same time as carbon N, P, K, bulk density, and moisture. The system response to elemental concentration is linear and since it probes constant volume (saturation volume) it is directly proportional to the number of carbon atoms in that volume, i.e., carbon concentration, gC/cm3. The response function of the INS system can be expressed analytically as a multidimensional integral over space, energy and time and solved numerically using Monte Carlo method. Preliminary results from system simulations showing dependence on the soil bulk density and moisture together with the estimates of the sampled depth, footprint and volume are presented. Initial results of field stationary and scanning measurements are also included.

B.48: Impact of land use and land-use change on CO2 emissions in Mexico

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The Land use sector of Mexico is the second most important source of greenhouse gas emissions. However, emission estimations were mostly derived from default values. In this study we present the update of emissions from land use, land-use change and forestry (LULUCF), based on national databases, with the application of a few minor IPCC default values, where no data were available. Land use maps of 1993 and 2002 were compared to analyze the spatial variation of land-use change. National geo-referenced forest inventory data of 1993 were made available to calculate the biomass densities in each land-use class. Published and unpublished increment data were used to estimate biomass increase in abandoned land and managed forest. The impact of land-use change on soil carbon was derived through comparison of soil organic matter content of 4,500 geo-referenced soil sampled nationally.

We estimate that the LULUCF sector emit 86,876 Gg CO2 and 1,273 Gg non-CO2 gases annually (127 Gg CH4, 1,113 Gg CO, 1 Gg N2O and 32 Gg NOx). The CO2 emissions results from a balance between 64,484 Gg CO2 emissions from burning and decomposition of biomass due to forest conversion, 30,344 Gg CO2 emissions from mineral soils, 4,932 Gg CO2 emissions from managed forests and a sink of 12,883 Gg CO2 on abandoned lands.
The total uncertainty of the emission estimation amounted to 34.4% (± 29,894 Gg CO2). Based on the results of the study the major sources of uncertainty are recognized and improvements of data collection and analysis are suggested for future emission inventories. We recommend the Mexican government to set up a continuous monitoring system with the aid of satellite imagery and systematic field collection efforts that would reduce the uncertainty and would able the government to report emissions on a regular basis.

Coastal and Oceanic Measurements

C.1: A preliminary synthesis of air-sea CO_2 flux and an exploration of control mechanisms in the US east coast and other western boundary current shelves

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It is increasingly recognized that air-sea CO_2 flux and carbon budget in continental margins represent an important knowledge gap in global carbon cycling research. In the east coast of the North America, until very recently, the US Mid-Atlanta Bight is the only shelf that annual air-sea CO_2 flux was measured (by Takahashi, DeGrandpre et al.). While this shelf acts as a moderate sink of atmospheric CO_2, its overall carbon flux to the open ocean is not known. The central part of the South Atlantic Bight (SAB) was reported as a source of CO_2 to the atmosphere as a result of decomposition of organic matter exported from rivers and the productive salt marshes. Our recent whole shelf seasonal survey, however, defines the entire SAB as a weak CO_2 sink. Large seasonal changes occur mostly in the spring and fall. It appears that temperature is the most important control on surface pCO_2 and that organic carbon production and respiration are closely coupled in the SAB. Preliminary data collected in the Gulf of Mexico (GOM) suggest that air-sea CO_2 flux and carbon recycling are extremely patchy in the North America's largest marginal sea with the freshwater dominated area being a strong CO_2 sink and the rest of GOM most likely being a CO_2 source. Because of its large area and strong signal, the size and direction of the CO_2 flux in the GOM would have a major influence on the overall coastal ocean air-sea CO_2 budget in the North America (see my poster on the 25&26 meeting). In the northern end of the North America east coast, the Gulf of Maine and the Nova Scotia shelf is most likely a moderate sink of atmospheric CO_2 although reliable data are limited to its southern-end (Vandemark and Salisbury, per. Comm.). Characteristics of these and a few other western boundary current shelves are compared. Temperature, terrestrial input, shelf depth and stratification, existence of spring bloom etc are identified as the most important factors controlling the carbon cycling and the size and direction of air-sea CO_2 flux.

C.2: Air-sea CO_2 flux and carbon budget in the Gulf of Mexico: State of knowledge and research initiatives in North America's largest marginal sea

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The Gulf of Mexico (GOM) is a subtropical marginal sea with 80% of the area being continental margin. The GOM may be divided into four parts: the West Florida Shelf (WFS); Northern GOM; East Mexico shelf; and Yucatan-Campeche shelf. The carbon cycle in the GOM is distinctly different between the river-dominated and non-river-dominated regions. In the former, rivers deliver large amounts of POC, DOC, and sediments to ocean margins, but the fractions of recycled vs preserved carbon are not known. Nutrient-rich river water also supports high levels of primary production in the GOM shelf, particularly, in the Mississippi River plume. Many of the key features of the carbon cycle in these river-dominated regions are centrally dependent on an understanding of the rates of organic carbon degradation in the water column and sediments. In contrast, the other shelves in the GOM have minimal river influence and receive nutrients mostly from subsurface water brought in by meanders and eddies of the Loop Current, or by upwelling of deeper water at the shelf break. The overall metabolic state of the Gulf Coast is not well constrained, however, with some studies suggesting net autotrophy (in river dominated area) and others implicating net heterotrophy. The net effect of major processes on air-sea CO_2 exchange in the GOM is equivocal, as key identified forcings (river, storm etc.) can potentially drive both super- and undersaturation of surface-water pCO_2. Surface-water pCO_2 data are scarce in the GOM, with the exception of a few studies in the area of the Mississippi River Plume, in the WFS, and a model prediction for the northern GOM. We know of no studies of CO_2 distributions or fluxes in the East Mexico or Campeche-Yucatan shelves.
NOAA will conduct a large scale survey that will include measurements in the GOM and along the southeastern U.S. as well as VOS- and mooring-based CO_2 measurements. We recommend 1) that carbon cycle in various parts of the GOM be studied with a contrast of freshwater and terrestrial material input in mind; 2) that a combined approach of underway shipboard survey, VOS and in situ mooring, and satellite remote sensing be adopted; and 3) that international collaboration with the Mexico partners is necessary.

C.4: Carbon Sources and Sinks in the Mexican Pacific Coastal Waters

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The measurement of variables related to the CO2 system in Mexican coastal waters has been very scarce and sporadic. Most of the measurements to estimate carbon sources and sinks have been done mainly in two regions: the Gulf of California and the coastal waters off Baja California (Southern portion of the California Current). The subtropical and tropical waters have not been studied. Most of the measurements to estimate the pCO2 in the Gulf of California have done based on measurements of pH, total alkalinity and sometimes also total inorganic carbon. It is until very recently that continuous spatial pCO2 measurements have been done off Baja California. Continuos temporal pCO2 measurements from a buoy off Ensenada, B.C. started also in July 2006. A review of previous and actual measurements of pCO2 is presented for the Mexican Pacific coastal waters.

C.9: High frequency CO_2 variability in North American coastal waters

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In 2006, three autonomous pCO_2 systems were deployed on surface moorings in coastal waters representing three very different biogeochemical provinces of the North American coast. One system was deployed off the west coast approximately 84 km northwest of Aberdeen, WA in 132 m of water. This region has a relatively narrow shelf influenced by coastal upwelling and moderate seasonal temperature changes. A second pCO_2 system was deployed approximately 74 km southeast of Savanna, GA in 18 m of water. This mooring, located within the Gray's Reef Marine Sanctuary, is in a region characterized by a broad shallow shelf and somewhat smaller seasonal temperature changes. A third pCO_2 system was deployed in the Western Gulf of Maine near Portsmouth, NH in 65 m of water. This region has a large seasonal temperature cycle and is influenced by seasonal phytoplankton blooms. All three moorings show some degree of diurnal variability, but they have different characteristic variability patterns on timescales of weeks to months. We will compare the time-series records from these three sites and explore the possible mechanisms controlling this high frequency variability.

C.15: Temporal and spatial variation of air-sea CO2 fluxes in the West Coast of Baja California, Mexico.

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A clear seasonal CO2 fluxes cycle has been identified in the zone of the Mexican Pacific coast off Baja California using CO2 concentrations that were measured from 1993 to 2001. From about December to May (winter and early spring), the oceanic and shelf surface water was a sink for atmospheric CO2, however the rest of the year it was a strong source of CO2. The strong sink area started in the coast north of Punta Eugenia (Up to latitude 27).While the coastal system become a source from June through November. It was clear that all the Baja California coast was an intense source of CO2. Data from 1994 show the variation of pCO2 from February to August with the dominance of the low-CO2 early in the year in the waters over the shelf area making the region a net sink during upwelling season but changing to a source of CO2 during August in all the area with higher fluxes south of latitude 28. The annual flux positive average value suggest this zone as a source of CO2 to the atmosphere.

Mid-Continent Intensive Study

D.3: Investigation of Carbon Cycle Processes within a Managed Landscape: Recent Progress and Future Research

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Our research is designed to improve the scientific understanding of how carbon is cycled between the land and atmosphere within a heavily managed landscape that is characteristic of the Upper Midwest. In this poster presentation we present key results from experiments conducted from 2002 to present and outline future research plans. Our results focus on: 1) The impact of land management on the long-term (~5-year) carbon balance of agricultural ecosystems; and 2) Development and implementation of micrometeorological and stable isotope techniques to trace the flow of carbon between land and atmosphere at a variety of temporal and spatial scales.

1. Near-continuous eddy covariance flux measurements have been made in conventional and alternative corn-soybean rotation systems since 2002 to evaluate their carbon sequestration potential. The alternative land management system consists of fall strip tillage combined with a spring and/or fall cover crops. The first complete biennial rotation (2001 through 2003) revealed that both systems were a small net loss of approximately 90 g C m-2 to the atmosphere indicating that modified tillage practices and the use of a spring oats cover crop had little or no impact on enhancing carbon sequestration. However, experiments involving a winter rye cover crop planted during fall 2004 resulted in an additional 175 g C m-2 y-1 (fall 2004 to fall 2005) relative to the conventional treatment. But what are the potential longer-term feedbacks of increased carbon inputs? Preliminary analyses of flux data collected during the following year (fall 2005 to fall 2006) indicate a substantial enhancement (about 40%) ecosystem respiration as microbial activity adjusted to the added substrates. From a greenhouse gas management perspective, these preliminary findings suggest that the initial carbon gain from cover cropping could be used more effectively as an alternative fuel source (i.e. Ethanol production) rather than attempting to rebuild soil organic matter, which is a relatively slow and inefficient process when considering the immediate need to lower atmospheric carbon.
2. The stable isotope composition of CO2 in the atmosphere represents a potentially important signal of global change. Interpreting its variation, however, requires a sound understanding of the underlying biophysical processes. This ultimately requires improved ability to quantify isotopic fluxes between the land and atmosphere. We have conducted carbon isoflux experiments using tunable diode laser isotope systems combined with both flux-gradient and eddy covariance theory. The high temporal resolution of the CO2 isotope signals is providing new insights as to how photosynthetic discrimination and heterotrophic and autotrophic respiration vary with time and impact the isotopic composition of the atmosphere. These new data should lead to a better understanding of how climate variations and changes in land use impact the partitioning of net CO2 exchange. Our poster will highlight some of these results at the ecosystem scale and our plans for extending these new techniques to a tall tower (240 m) site to gain a greater understanding of carbon cycling processes at the landscape scale.

D.6: Carbon Sequestration Potential in Midwest Agricultural Land and Restored Grasslands (Fermiflux) study

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Two new AmeriFlux sites started measuring CO_2 and energy fluxes at the Fermi National Environmental Research Park in the Midwestern United States, a region previously identified by the NACP as needing increased coverage. The AmeriFlux towers are located on (1) cultivated land under soybean-corn rotation, with conservation tillage management of the soil, and (2) long-term-cultivated land restored to native vegetation that undergoes fire treatment every other year. Both sites are highly representative of current management practices in the Midwest. Conservation tillage (no tillage after soybean crop) is used in 45% of the area comprising the U.S. Corn Belt. The restored land at Fermilab represents management practices applied under the CRP. At the prairie site, we expected increases in plant productivity and high NEE during 2005 as a result of fire treatment. However, plant biomass in 2005 was similar to 2004 and lower than in 2006. This could be caused by the extremely dry conditions plants experience during the growing season of 2005. Nevertheless, NEE was 140 g C m^{-2} higher in 2005 compared to 2006 when an invasive specie, *Melilotus alba* (M.), greatly affected ecosystem fluxes. Biometric and annual NEE estimates of NEP correlated extremely well at the prairie site, resulting in 5.5 Mg C $h^{-1}y^{-1}$ in the year 2005. About 14% of NEP remained in the soil each year, with climate and vegetative growth exerting the greatest controls on C sequestration. Our results will (1) reduce uncertainty about belowground C cycling and its magnitude, (2) indicate the potential of restoration practices as C sequestration strategies, and (3) produce data to constrain models.

D.8: The Bondville Intensive: An Integrated, Bottom-Up Approach to Estimating Regional Fluxes

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Starting in the summer of 2005, this intensive campaign was developed to test a number of different approaches to scaling carbon, water, and energy fluxes over agricultural landscapes. This campaign takes place in Champaign County, Illinois over a soy/maize agroecosystem. The approaches vary from direct measurement and scaling using land cover maps, to remote sensing approaches using hyper- and multi-spectral methods. Measurements were simultaneously taken at leaf, plant, tower (field), aircraft (sub-regional), and satellite (regional) scales. These high resolution co-located data sets are currently being used to populate models and compare different approaches for estimating fluxes at several scales. While temporal data are being collected at tower sites throughout the year, most of the additional data has been collected during the growing season, between June and September. Preliminary analyses indicate strong between several of the methods.

Managed Forests and Woodlands

E.10: Carbon sequestration project, from integral management of the common resources options, for indigenous and rural communities in Oaxaca, Mexico.

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Servicios Ambientales de Oaxaca (SAO) has been development a methodology for evaluation the carbon sequestration potential capability in 15 indigenous and rural communities at Oaxaca State.

Before selecting communities to participate in the project, it was necessary for each one to complete a land ordination study to evaluate land use. The project considers the management of protected and community areas and intervention in the following productions systems:
a) Restoration of acahuales (fallow land), b) Sustainable agriculture, c) Agroforestry systems, d) Enriched shaded coffe and e) Forest restoration.

The carbon sequestration potential averages are about 18,000 MgC/yr; SAO has developed a carbon pilot project on this communities. The state of Oaxaca, Mexico held the highest biodiversity in the country, concentrates almost 12,974 species of flora (8,431) and fauna (4543) and contains a considerable number of endemism; 80% of the land is own by communities and Ejido.

E.11: A Modelling Framework for Carbon Stock and Sequestration at Regional Scales and Scenarios of Synergistic Co-Benefits Through Land Use Changes in Agricultural and Forested Lands

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A methodological framework for the assessment of carbon stocks and sequestration in tropical and sub-tropical lands was designed. The formulation and identification of scenarios, where enhancing carbon sequestration synergistically increases the conservation of biodiversity, the prevention of land degradation, as well as the improvement in crop yields through land use change and management practices is one of the main objectives of the framework. It integrates field measurements, computer modelling tools (i.e. customized, spatially-explicit soil organic matter turnover simulation models) and GIS. The framework was applied and tested through three case studies in Mexico and one in Cuba. Issues concerning the spatial and attribute minimum datasets to run the models, and the coupling of models to GIS were addressed. Results indicate that reasonably accurate estimates in carbon sequestration can be obtained land alternative best soil organic matter management practices identified. As far as food security is concerned, modeling results showed that “slash-and-burn” agriculture through shifting cultivation, present in one of the case studies, can be stabilized and transformed into a “slash-and-mulch” system, resulting in increased crop yields and food security for an average family size (6) in that area, while enhancing biodiversity and preventing land degradation through the judicious management of organic matter. The methods and tools in the framework may be applicable to other landscapes where the assessments of carbon stock and sequestration potential, and other environmental benefits are needed, and are inextricably tied up to the conservation of biodiversity and the prevention of land degradation.

Arctic and Boreal Ecosystems

F.4: Carbon Fluxes From Canadian Forests and Peatlands: the Fluxnet-Canada Perspective

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Hank Margolis, Fluxnet-Canada Research Network, hank.margolis@sbf.ulaval.ca (Presenting)
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The potential importance of the biosphere to climate change is highlighted by the fact that annual C fluxes from terrestrial ecosystems are an order of magnitude greater than fossil fuel emissions. Canada's vast land area provides us with both a national opportunity and a global responsibility to understand, manage, and predict the role of our terrestrial ecosystems in climate change.

By March 2007 the Fluxnet-Canada Research Network will have been in operation for five years and conducted carbon flux measurements at a total of 36 network or associated sites along an east-west continental transect. Year-round measurements of the net exchange (flux) of C, water and energy between these sites and the atmosphere will have been made at 26 of these sites, while the other ten sites will have been measured periodically during the growing season. The network studies a) the relationship between the inter-annual variability of C fluxes and climate, b) the effect of disturbance on C fluxes, c) the relationship between ecosystem productivity and net C fluxes, and (d) ecosystem and climate models that allow extrapolation in space and time. The knowledge gained from these studies will allow us and others to provide better estimates of the potential for C uptake, emission and long-term sequestration by Canadian forests and peatlands. We will present key results from the network.

F.5: Characterization of frozen and thawed seasons in the terrestrial high latitudes with spaceborne microwave remote sensing: Relationships with land-atmosphere CO2 exchange

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Landscape transitions between seasonally frozen and thawed conditions occur each year over roughly 50 million square kilometers of Earth's Northern Hemisphere. These relatively abrupt transitions represent the closest analog to a biospheric and hydrologic on/off switch existing in nature, affecting surface meteorological conditions, ecological trace gas dynamics, energy exchange and hydrologic activity profoundly. We utilize time series satellite-borne microwave remote sensing to examine spatial and temporal variability in seasonal freeze/thaw cycles for the pan-Arctic basin and Alaska. Regional measurements of spring thaw and autumn freeze timing are derived using daily brightness temperature measurements from the Special Sensor Microwave Imager (SSM/I) and the SeaWinds-on-QuikSCAT scatterometer. We examine relationships between freeze/thaw timing as related to sensor, satellite overpass time, and landcover, and in relation to regional biospheric activity indicated by atmospheric CO2 measurements. Spatial and temporal patterns in regional freeze/thaw dynamics show distinct differences between North America and Eurasia, and boreal forest and Arctic tundra biomes. Annual anomalies in the timing of thawing in spring also correspond closely to seasonal atmospheric CO2 concentration anomalies derived from NOAA CMDL arctic and subarctic monitoring stations.

F.9: Progress and Prospects at the Boreal Ecosystem Research and Monitoring Sites

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The Boreal Ecosystem Research and Monitoring Sites (BERMS) program is a multi-year, inter-disciplinary study of the carbon, water and energy cycles of the southern Canadian boreal forest in relation to inter-annual climate variability, ecosystem type, and stand age following disturbance by fire and harvest. The three primary BERM sites (Old Aspen, Old Black Spruce, and Old Jack Pine) were established in 1994 as part of the Boreal Ecosystem-Atmosphere Study (BOREAS) and have continued since 1997 as part of BERMS and since 2002 as part of the Fluxnet-Canada Research Network. In addition, six satellite sites have been established in young forest stands following disturbance by fire and harvest. This poster will highlight our findings on inter-annual variability in the carbon and water budgets of the southern boreal forest and forest carbon dynamics following disturbance by fire and harvest. It will also outline the planned BERMS contributions to the Canadian Carbon Program, 2007-2010.

F.10: Interannual to decadal changes in area burned in Canada from 1781-1982 and the relationship to Northern Hemisphere land temperatures

Martin Philippe Girardin, Canadian Forest Service, martin.girardin@rncan.gc.ca (Presenting)

Temporal variability of Annual Area Burned in Canada (AAB-Can) from AD 1781-1982 is inferred from tree-ring width data. The rationale in this use of tree rings is that annual

radial increments produced by trees can approximate area burned through sensing climate variations that promote fire activity. This study demonstrates that the upward trend in AAB-Can is unlikely to be an artefact from changing fire reporting practices and may have been driven by large-scale climate variations. Fire is recognized as driving much of the boreal forest carbon balance in North America. Greater amounts of fire owing to human-induced climate warming could result in a situation where the Canadian boreal forest would be a net carbon source.

The database of total area burned per year in Canada is used as the predictand. A set of 54 multicentury tree-ring width chronologies distributed across Canada is used as predictors. A linear model relating the predictand to the tree-ring predictors is fitted over the period 1920-1982. The regression coefficients estimated for the calibration period are applied to the tree-ring predictors for as far back as 1781 to produce a series of AAB-Can estimates.

The AAB-Can estimates account for 44.1% of the variance in the observed data recorded from 1920-1982 and were verified using a split sample calibration-verification scheme. Correlation analyses with fire data from ten ecozones and with 500-hPa geopotential heights show that estimates are representative of fire weather and fire activity variability over the majority of fire prone ecozones of Canada. The statistical reconstruction indicate that the positive trend in AAB-Can from 1970-1982 was preceded by three decades during which area burned was at its lowest during the past 180 years. Correlation analysis with Northern Hemisphere warm season land temperatures from the late 18th century to present reveal a positive statistical association with these estimates.

F.11: The impacts of North American boreal fires on terrestrial carbon cycling and atmospheric trace gas concentrations

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Fires in the boreal region play an important role in the North American terrestrial biome. In particular, boreal fires combust not only aboveground biomass, but dead organic matter that lies on top of mineral soils in forests and peatlands. During boreal fires, carbon emissions from forests with deep organic layers and peatlands can be as high as 4 to 8 kg/sq m. As a result of recent climate change, the average burned area in the NA boreal region has more than doubled, and the deep organic layers are becoming more vulnerable to burning because of warming of permafrost and drying of peatlands. Large fire years at regional scales have become more frequent, and recent studies show that the emissions released during the summer-time events have a large impact on the atmospheric concentrations of CO2, CO, and CH4 across North America. The NACP has sponsored research to better quantify depth of burning in Alaskan forests and peatlands and similar efforts have been ongoing or are being planned within the Canadian Forest Service. A significant opportunity exists to carry out collaborative research that would: (a) develop a consistent methodology to estimate depth of burning as a function of environmental conditions in forests and peatlands across the North American boreal region; (b) incorporate these observations in the different models used to study terrestrial carbon cycling and estimate trace gas emissions (e.g., the Canadian Forest Carbon Accounting System, TEM, CASA); and (c) evaluate the effects of variations in burned area and depth of burning on terrestrial carbon storage and atmospheric concentration of atmospheric greenhouse gases.

F.12: Using knowledge of environmental control of the onset of photosynthesis to predict the impact of global warming on springtime carbon uptake by northern forests

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Present work with eddy covariance is showing the importance of early spring growth on the carbon balance of forest ecosystems in the Canadian boreal forest. Global warming will increase photosynthetic production of northern forest ecosystems in early spring, and proper prediction of this effect is important to estimates of future carbon cycling. We identified the onset of photosynthesis in a forest ecosystem whose soil freezes below rooting depth as occurring when soil temperature first rises and becomes isothermal at 0°C. Soil temperature remains at 0°C for approximately 20-30 days, mostly covering the period of snowmelt. Using hydrological knowledge of snow melt dynamics we are developing a model for predicting the onset of photosynthesis. We will calibrate this model with data from eddy covariance towers in Canada's boreal forest. Secondly, we will develop a model for predicting ecosystem photosynthesis in spring for a balsam fir ecosystem and compare predictions based on current and predicted future climates to assess the impact of global warming. Progress on this work will be reported at the conference.

F.13: Simulating Dissolved Organic Carbon Dynamics in Boreal Forests

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Dissolved organic carbon (DOC) is the proportion of organic carbon in vegetation that can be dissolved into precipitation and transported into soil layers with the movement of precipitation water. DOC in the soil is the most active element and significantly contributes to the carbon (C) /nitrogen (N) cycling and balance of terrestrial ecosystems. During its movement, DOC can be transported from top soil to deeper soil layers and stored as soil organic matter, or leached as a transfer of energy, carbon, and nutrient from terrestrial to aquatic ecosystems, or evaporated into the atmosphere as CO2. Despite growing interests and extensive research in evaluating and analyzing the role of DOC in the C/N cycling of forest ecosystems in the last decade, modelling DOC flux and dynamics is still poorly developed, mainly due to the lack of a comprehensive understanding of the DOC dynamics and modelling efforts in forested soils. Recently, many field experiments have been implemented in the boreal forests and understandings of the controls on the production, consumption, and leaching of DOC from plant tissues and soils have greatly been expanded. In this study, a process-based soil DOC model, TRIPLEX-DOC, has therefore been developed based on the achievements of DOC controls. It was designed as an additional module of TRIPLEX model and is capable to simulate dynamical variation and distribution of soil DOC and estimate DOC emissions, leaches, and storages in the boreal forest regions.

F.14: Assessing the vulnerability of boreal peatlands to changing climate and fire regimes

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Boreal peatlands are important reservoirs of terrestrial carbon. Peatlands globally cover 3-5% of the Earth's land-base, but store ~30% of the world's soil carbon and are situated primarily in boreal regions. It is unknown whether boreal peatlands will continue to represent a net sink for atmospheric CO_2, or whether changes in the Earth's climate will cause peatlands to release stored carbon back to the atmosphere. Responses of peatland C fluxes to changes in climate or disturbance regimes are likely to influence atmospheric C concentrations, either through positive feedbacks (decomposition, fire consumption) that enhance warming or negative feedbacks (C uptake) that mitigate warming. As a result of recent climate change, average area burned in boreal North America has more than doubled, and deep organic soils in peatlands are becoming more vulnerable to burning. Ongoing work sponsored by the NACP is quantifying controls on deep organic soil consumption during recent severe fire seasons in Alaska. Collaborations with Canadian scientists are contributing to our understanding of the extent of, and controls on, peat fires across boreal North America. A significant opportunity exists to carry out collaborative research that would: (a) evaluate fire weather controls on area burned and consumption severity in boreal peatlands, (b) establish quantitative relationships between peatland hydrology, vegetation structure, and carbon cycling processes, (c) quantify post-fire radiative forcing caused by albedo changes and greenhouse gas emissions (CO_2, CH_4) in peatlands, and (d) evaluate effects of peat fires and other peatland disturbances on terrestrial carbon storage and atmospheric greenhouse gas concentrations.

F.15: Impacts of Soil Freeze/Thaw Dynamics on the North American Carbon Cycle

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Between 68 and 80 percent of North America experiences seasonal freezing and thawing with the relative influence of these processes on terrestrial carbon budgets generally increasing at higher latitudes and elevations. The timing and duration of soil freeze/thaw state are closely linked to vegetation phenology, and growing season dynamics in northern temperate, sub-alpine, boreal and arctic biomes. Variability in these environmental variables also has been shown to have dramatic impacts on spatial patterns, seasonal to inter-annual variability and long-term trends in terrestrial carbon budgets and surface-atmosphere trace gas exchange primarily through biophysical controls on both photosynthesis and respiration. These processes are strongly influenced by land cover and soil properties, as well as the timing and condition of seasonal snow cover. Based on this background, we will integrate remote sensing data sets, ground-based measurements, and numerical modeling to quantify the effects of soil temperature, soil freeze-thaw dynamics, and snow cover on seasonal to inter-annual variability in the North American terrestrial carbon cycle. Our overall goal is to understand the role of freeze-thaw processes in determining seasonal and inter-annual variability in terrestrial biomass, photosynthesis, respiration, and net CO2 fluxes over continental North America. Using remote sensing products, in situ observations, and a soil thermodynamic model, we will estimate soil temperatures and snow cover over North America at 25-km resolution for North America from 1981-2003 (23 years). We will feed these estimated soil temperatures and snow cover, along with additional remote sensing data, into an ecosystem model to estimate biomass and net carbon fluxes. Both models will use the North American Regional Reanalysis, so the resulting estimates of soil thermodynamic properties, biomass, and carbon fluxes will be optimally consistent with each other and with actual weather conditions in North America. We will statistically analyze these optimal carbon fluxes to understand the environmental drivers and biophysical responses regulating the spatial patterns and temporal variability in the North American terrestrial carbon cycle. Using standard Monte Carlo techniques, we will quantify uncertainty in our estimated carbon fluxes. Lastly, we will perturb our input data to assess the sensitivity of our estimated fluxes to long-term climate change.

Integrating Land, Coastal Margins, and Oceans

G.1: A large knowledge gap in the NACP: The role of intertidal marshes in the transfer of CO_2 between the atmosphere and the ocean

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Early recognition of coastal intertidal marshes as highly productive ecosystems led to the hypothesis that marshes contribute significant amounts of organic carbon to estuaries and the coastal ocean. This outwelling hypothesis was later challenged, at first because there were insufficient supporting data, and later because new data and more detailed models of estuaries did not reveal large fluxes of organic matter from marshes. The validity of the outwelling hypothesis is just one component of the larger issue of the trophic status of estuaries, and particularly the importance of estuarine heterotrophy on a global basis.

In recent years, my group has studied the coastal metabolic balance issue in the context of air-sea CO_2 flux with the goals of finding the source materials and mechanisms that support CO_2 evasion in coastal waters. Estuarine and nearshore waters in Georgia are nearly always highly supersaturated with respect to atmospheric CO_2. Some large flux values were estimated with perhaps great uncertainty for two main reasons. First, estuary-marsh systems are highly heterogeneous and of great dynamics, thus making water-air flux measurements less representative and meaningful. The second difficulty comes from not knowing precisely the areas of various subsystems (open water, marsh-plants, mud flat etc) thus making up-scaling to regional or global fluxes highly uncertain. Because of the extremely strong CO_2 signals and large uncertainties in the areas, special attention is called to address this knowledge gap in the boundary between the land and the coastal oceans within the context of the NACP.

Regional Analyses

H.3: The ORCA West Coast Regional Project: Ground measurements made across key vegetation gradients

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The ORCA West Coast Regional Project uses a physiological process model parameterized with remote imagery to make temporally and spatially explicit estimates of carbon stocks and fluxes across Oregon and northern California. In addition to assessing output against ground measurements of biomass (from forest inventory) and carbon dioxide flux balance (from eddy covariance towers) model output can be assessed against detailed ground measurements of carbon stocks and fluxes across key disturbance gradients that are deemed ecologically significant, management relevant, and that target suspected weaknesses in remote detection and model structure. Efforts are currently focused on four such gradients including: 1) clear-cut harvest Chronosequences in the Cascades and Coast Range, where measurements reveal that only the youngest stands exhibit negative NEP and that the age at which NEP becomes positive depends on climate and resource availability; 2) a wildfire severity gradient in Siskiyou Mountains, where measurements reveal that pyrogenic emissions are dependent on severity and that reductions in post-fire NEP are driven first by reductions in GPP not through increases in Rh; 3) a forest thinning gradient in the Sierra Nevada, where measurements suggest that belowground carbon dynamics are less sensitive to thinning than aboveground carbon dynamics and that increases in shrub productivity may quickly compensate for reductions in overstory LAI; 4) woody encroachment in the Steens Mountains, where we suspect juniper encroachment to increase NPP, and possibly GPP, but not necessarily NEP.

H.7: A multiple constraints model-data assimilation scheme to combine MODIS thermal and AMSR-E microwave image products for estimation of land surface variables and fluxes in tropical savannas

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This poster demonstrates the application of a multiple constraints model-data assimilation (MCMDA) scheme to the combination of AMSR-E soil moisture content (SMC) and MODIS land surface temperature (LST) in a coupled biophysical model for the tropical savannas of northern Australia. These methods are demonstrated with a view to their extension to other savanna regions and global biomes. The results show that, on their own, AMSR-E SMC data were poor constraints to the model. Incorporating LST data via the MCMDA framework ameliorated deficiencies in the SMC data and resulted in enhanced characterization of land surface soil moisture and energy balance. On average the model predicted wetter SMC values (~0.04 g cm^{-3}) and cooler LST's (~1.7 K) than the satellite image products.

In the MCMDA scheme, an objective function measures the mismatch between model-predicted and satellite-observed SMC and LST. Numerical search routines were employed to give an optimum choice of the tuning parameter g_{max}—the canopy-averaged maximum stomatal conductance—that minimized the objective function. In terms of RMSE, an optimal fit to both image product datasets resulted in an increase by 84% for predicted SMC and a 0.06% increase for LST relative to the fit to each dataset separately.

Also comparisons of model estimates of canopy stomatal conductance, g_c, and latent heat flux, λE, with those obtained from a MODIS evapotranspiration product revealed good agreement, with RMSE for $g_c = 0.5$ mm s^{-1} and for $\lambda E = 18$ W m^{-2}.

The MCMDA scheme's capability for handling multiple incommensurate datasets is of key importance for improved forecasting of land-air exchanges of water, energy and carbon in savanna systems around the world including North, Central and South America.

H.8: Quantifying surface fractional cover using remote sensing for improving land surface schemes of water and carbon fluxes in tropical savannas

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Quantification of the surface fractional cover is needed as a lower boundary condition to underpin accurate carbon, water and energy balance modeling in all land systems including those of North and South America. Our work in Australian tropical savannas seeks to integrate spectral data and vegetation indices from MODIS and Hyperion, with spectral libraries and fractional cover surveys from field campaigns, and high resolution "snapshots" of fine scale structure to define fractional cover of trees, green and dead grass, and bare ground.
Spatial resolution and spectral band location in the short wave infrared, particularly above 2000 nm limits sensitivity of MODIS spectral data to variation in dead and bare fractions. However, recent research has shown that spectral angular indexes from 7 band MODIS data show promise in improving fractional cover retrievals. We are seeking to develop a processing sequence that maximizes the information on fractional cover that can be extracted from sub-optimal combination of data from temporal, spectral and spatial domains.
Up to this point, we have found that:
1. Time series of MODIS NDVI or EVI can be decomposed to provide information on the proportions of perennial and annual vegetation.
2. Spectral signatures from Hyperion can be convolved to MODIS bands and used in a combination of spectral unmixing and time series analysis to infer some information about fractional cover.
3. MODIS 16-day composite reflectance (MOD43) can detect the effects of grazing around livestock water points in those vegetation types with low tree cover.
4. Angular indexes from MODIS spectra pivoting on the SWIR1 band offer significant potential for improving fractional cover retrieval.
In January, we will report results from analysis of MOD43spectral and index time series in relation to field and Hyperion spectra convolved to MODIS bands, and in relation to high resolution imagery and ground data defining fractional cover. A processing framework to maximize fractional cover information for these savannas will be outlined an its potential extension to North, Central and South American land systems will be discussed.

H.9: Markov chain Monte Carlo: Practical Aspects of its Application to Terrestrial C-Cycle Model-Data Assimilation

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There is an ever increasing realization that, for most environmental modeling problems, greater insight is gained from the utilization of multiple "orthogonal" datasets than from any single dataset. To this end, there remains the question of how best to combine these different and disparate sources of data with physical models.
Multiple constraints model-data assimilation (MCMDA) provides a framework within which data and models are combined to estimate land surface variables and parameters. A key element to MCMDA is the numerical search algorithm used to obtain the optimal set of model parameters that minimizes a cost function comprised of observational data and model predictions.
In this poster we explore some of the practicalities and challenges faced when Markov chain Monte Carlo (MCMC) is used as a global search algorithm to estimate the parameters and initial conditions of a simple C-cycle biophysical model. Specifically, two versions of the Metropolis-Hastings (MH) algorithm are applied to synthetic datasets of remotely-sensed observations (including land surface temperature and NDVI), flux tower measurements and in situ data.

H.12: The ORCA West Coast Regional Project - Use of Top-Down Modeling in a Regional Carbon Budget Approach to Estimate Gross Carbon Fluxes for Oregon-California

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The ORCA project aims at determining the regional carbon balance of Oregon and northern California (see also Law et al., this meeting), with a special focus on the effect of disturbance history and climate variability on Carbon sources and sinks. ORCA provides a regional test of the overall NACP strategy by demonstrating bottom-up and model-data fusion approaches to derive carbon balances of a larger area.
The top-down modeling component of ORCA focuses on coupling simple process models for GPP, RA and RH with atmospheric transport modeling to interpret measured CO2 concentration data. This approach builds on high-resolution remote sensing products (e.g. Landsat, MODIS) as well as spatial meteorological datasets (EDAS, DayMet) to drive the models. We employ STILT (Stochastic Time-Inverted Lagrangian Transport) footprints to determine the relative influence of each part of the region surrounding the observation site on the measured concentrations, and to identify the composition of landcover types within this area. The information on the contribution of fluxes emitted by the different landcover types to the CO2 measurements is subsequently used to optimize base rates in the parameterization of the process models.
We present a proof-of-concept of the ORCA top-down modeling approach by comparing modeled to measured CO2 concentration data. This comparison also addresses the uncertainties introduced by different components of this approach. To demonstrate the effect of the improved process model parameterization, the results will be compared to the regional fluxes derived by the ORCA bottom-up component.

H.15: An Analysis of Regional Carbon Stocks Estimates Using Airborne and Spaceborne Lidar in Quebec

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We are evaluating the potential of lidar data from the GLAS-ICESAT sensor to measure aboveground carbon stocks at the regional level in Quebec. In August 2005, we conducted flights using the Portable Airborne Lidar over (1) a range of ground plots and (2) along five, several-thousand-km long, north-south transects of GLAS data collected in October 2003 (Collection 2a). This information was integrated together with Landsat land cover and SRTM topographic data. The strongest relationships between PALS-derived biomass and different measures of vegetation height from GLAS (n~8000) varied between ecozones and were strongest in the northern temperate zone comprised largely of deciduous and mixed forest. The relationship between PALS biomass and GLAS height was stronger for pulses that had homogenous land cover. The equations that we developed allow us to use GLAS data to estimate of carbon stocks for the entire landmass of Quebec that lies south of the treeline.

H.20: Modeling Complex Effects of Multiple Environmental Stresses on Carbon Dynamics of Mid-Atlantic Temperate Forests

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We used our GIS variant of the PnET-CN model to investigate changes of forest carbon stocks and fluxes in Mid-Atlantic temperate forests over the last century (1900-2000). Forests in this region are affected by multiple environmental changes including climate, atmospheric CO2 concentration, N deposition and tropospheric ozone, and extensive land disturbances. Our objectives are to gain mechanistic understanding of the complex interactive effects of changing environmental factors on forest carbon dynamics, and to partition the forest carbon responses to different causes. Our results indicate that, for the whole forest area in the Mid-Atlantic, net primary productivity (NPP) increased by 25% over the last century due to chronic changes in climate and atmospheric chemistry. Among these factors, change in climate increased NPP by 4%; interannual climate variability caused 7% lower NPP; and changes in atmospheric chemistry had the dominant impact of increasing NPP by 34%, while 5% of this impact was further reduced by the interaction with interannual climate variability. With consideration of land disturbances, NPP may end up increasing more due to a greater response to N deposition which may compensate for N loss in disturbed soil pools. Annual net ecosystem productivity (NEP) fluctuated annually and was affected primarily by climate variability. This research shows that changes in atmospheric chemistry could be important driving variables that affect net carbon change in regions where air pollution is a significant factor.

H.24: Distribution of Aboveground Carbon Stock in North American Forests

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There is a general agreement that the terrestrial ecosystems in Northern Hemisphere are a significant sink of atmospheric carbon. However, the uncertainties in geographic distribution of this sink and its spatial and temporal variations due to changes in human and climate forcing are substantial. Consistent and spatially refined distribution of carbon

stock and its changes through time provide measurement-based constraints on estimating both the carbon uptake of ecosystems and their sustainability through time. This paper summarizes the methodology and the results from a NASA sponsored study to estimate the carbon stock in North American forests at the turn of 21th century, circa 2000. The goal of the study was to integrate remote sensing data from MODIS, SRTM, JERS, and Radarsat and forest inventory plots from US and Canadian forest service to estimate the spatial distribution of above ground forest biomass in North America. We report the results of the study in two parts. The first part focuses on the methodology and provides the distribution of carbon stock in forests of northeast and southeast regions of the US. The second part of the paper shows how the quality of the data and the errors associated with the methodology create uncertainties in measuring the carbon stock and evaluating the sink and source terms on the regional scale.

H.29: Carbon Content and Changes in Soils of the Forestry Sector of Mexico

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Soil C (SOC) changes due to land use and land use changes in the forestry sector (LULUCF) in Mexico's soils (1993-2002) were analyzed. A reduced standardized database (4422 samples of SOC, 0-30cm depth, adjusted bulk density) built from available sources was used. SOC data were first spatialized on a soil unit map 1: 250,000 (FAO 68, INEGI, series II), then expressed in terms of IPPC soil units, and finally spatialized again on a soil use unit map. This exercise yielded the SOC ton/ha per soil and vegetation units. The surface comparison (1993-2002) of each soil/vegetation unit was used as a criterion for SOC change. Low activity clay (LAC) showed lower SOC values (70.4 ton/ha) than volcanic and high activity clay soils (HAC, 93.7 and 91.3 ton/ha, respectively) but higher than sandy and wetlands (49.4 and 41.6 ton/ha). Soil unit and climate conditions determine SOC accumulations. Mangroves and temperate and tropical forests accumulated the highest SOC quantities (80 a 160 ton/ha), while the low tropical forest on LAC accumulated the lowest (< 70 ton/ha). In Mexico soil C emissions and capture due to LULUCF in the period 1993-2000 were 74,317 and 35,077 Gg C respectively, i.e. a net emission of 8,257 Gg C per year or 30, 277 Gg of CO_2 equivalent

H.30: Simulating carbon balance in US agroecosystems under present and future climates

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Agroecosystems are dynamic components of the biosphere from the viewpoint of the carbon balance because of the influence of human management on the a) size and fate of net primary productivity, b) size and longevity of the soil carbon pool, and c) lateral transfers and fate of carbon due to erosion and deposition. We used EPIC to develop national-scale estimates of the soil carbon balance under different scenarios of management and climate change. The EPIC model simulates the carbon balance with explicit representation of net primary productivity, soil storage, heterotrophic respiration, transport via erosion, and loss via leaching. Representative modeling units were created to capture the climate, soil, and management variability at the 8-digit hydrologic unit (USGS classification) watershed scale. Each watershed was assigned a major crop system: corn, soybean, spring wheat, winter wheat, cotton, hay, alfalfa, corn-soybean rotation or wheat-fallow rotation based on information from the National Resource Inventory. Each watershed was simulated with conventional and no tillage as well as with and without irrigation. Climate change scenarios for two future periods (2015-2045 and 2045-2075) were selected from GCM model runs using the IPCC SRES scenarios from the UK Hadley Center and US DOE PCM models. Modeled crop yields were validated against historical USDA NASS county yields. Adoption of no tillage enhanced soil carbon in US agroecosystems by about 0.5 Pg C during a 30-year period. The climate projections of the PCM model had more positive impact on the soil carbon balance than those predicted with the Hadley model.

H.31: ORCA West Coast Regional Analysis

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The project objectives are to reduce uncertainty in understanding C sources and sinks, and to determine the effects of disturbance and variation in climate on the regional carbon balance in the western U.S. over the past 30 years. We combine a spatially nested hierarchy of observations with bottom-up and top-down modeling to estimate carbon stocks and

fluxes over the region (Oregon and Northern California). Field observations are used for model parameters (e.g. foliar nitrogen and SLA from 200 extensive plots), for look-up tables (e.g. proportions of different biomass pools burned off in wildfires), and for development of remote sensing algorithms (e.g. for mapping LAI). Forest inventory data are used to evaluate model outputs (e.g. wood mass), and tower flux and carbon dioxide concentration data are used for parameter optimization in model-data fusion. We have begun application of a diagnostic carbon flux model (driven with MODIS data) which is integrated with the STILT model for atmosphereic transport. Our bottom-up scaling has been used to generate a carbon budget for Oregon. Landsat resolution (30m) remote sensing provided the basis for mapping land cover and disturbance history, identifying major fire and logging events over 30 years. For net ecosystem production (NEP), ecoregion-specific parameters and distributed meteorology were used to drive Biome-BGC. For net biome production (NBP), we used county harvest statistics for logging removals, USDA statistics for crop removals, and remote sensing based estimates of area burned and our mapped biomass estimates for fire emissions. Evaluation of our modeled carbon pools and flux was by reference to flux tower data, extensive field plots, and forest inventory data. All of the predominately forested ecoregions were significant NEP sinks. Agricultural ecoregions were also NEP sinks because decomposition of crop residues did not balance NPP. Crop and forest harvest removals amounted to about half of the NEP, so state-wide NBP remained positive most years.

H.32: Evolution of carbon pools and emissions from land use change process in the Huahutlas´s Sierra in Morelos, Mexico.

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This study is focused on quantify the rate of loss of vegetation cover and land use changes, in order to determinate the amount of carbon pools and emissions in tropical dry forest ecosystems, present in Huahutlas´s Sierra.
The vegetation cover suffers a deterioration process derived from mining activities, and water pollution. Other activities like cattle were abandoned and the people of the place preset a migration process to another city or to the United States.
Analyses show that deforestation is not related with population growth, but deterioration is connected with migration and carbon stocks losses. Preservation of the vegetation cover and biodiversity of the state of Morelos, is essentially related with indigenous territories and carbon mitigation options.

Continental Carbon Budgets and Analyses

I.21: Terrestrial Carbon Sinks for the United States Predicted from MODIS Satellite Data and Ecosystem Modeling

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A simulation model based on satellite observations of monthly vegetation cover from the Moderate Resolution Imaging Spectroradiometer (MODIS) was used to estimate monthly carbon fluxes in terrestrial ecosystems of the conterminous United States over the period 2001-2004. Predicted net ecosystem production (NEP) flux for atmospheric CO2 in the U.S. was estimated as annual net sink of about +0.2 Pg C in 2004. Regional climate patterns were reflected in the predicted annual NEP flux from the model, which showed extensive carbon sinks in ecosystems of the southern and eastern regions in 2003-2004, and major carbon source fluxes from ecosystems in the Rocky Mountain and Pacific Northwest regions in 2003-2004. As demonstrated though tower site comparisons, NPP modeled with monthly MODIS Enhanced Vegetation Index (EVI) inputs closely resembles both the measured high- and low-season carbon fluxes. Modeling results suggest that the capacity of the NASA-CASA model to use 8-km resolution MODIS Enhanced Vegetation Index (EVI) data to predict peak growing season uptake rates of CO2 in irrigated croplands and moist temperate forests is strong.

I.31: Progress Toward Monthly Resolution Fossil-Fuel-Derived Carbon Dioxide Emissions for the Countries of the North American Carbon Program

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Analysis of national statistical databases has allowed for the widely-used data-set on annual, fossil-fuel-derived, carbon dioxide emissions (maintained by the Carbon Dioxide Information Analysis Center (CDIAC)) to be subdivided into monthly time intervals. This analysis focused on statistical parameters that could proxy for the solid, liquid, and gaseous fuels consumed in each country at monthly time scales. An intermediate product of this analysis was the fraction of the annual total fuel consumption occurring in each month for each fuel. Monthly fractions were multiplied by the annual carbon dioxide emissions values to obtain monthly emissions estimates for each fuel type. A benefit of this approach is monthly and annual emissions time series that are mutually consistent.

This poster presentation will give monthly emissions for multiple years for the United States, Canada, and Mexico. The monthly data by state and province provide enough detail to begin to understand how the annual cycle of emissions varies spatially (i.e., whether emissions peak in the summer, in the winter, or are relatively uniform throughout the year). Collaboration is being sought to improve the state/provincial detail in the data time series, as well as in compiling additional statistics related to monthly fossil-fuel use. Please see/contact any of the co-authors of this poster if you are interested in such a collaboration.

I.32: Estimating forest properties across large landscapes in the Canadian Boreal Forest

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Large scale estimates of carbon stocks and changes in these stocks across the Canadian Boreal forest presently rely on periodical forest inventories coupled to empirical growth and yield models and expansion factors to convert tree-level measurements of diameter and height to plot-level merchantable volume and ultimately to landscape-level biomass and carbon content. We are presently developing a suite of methodologies destined to improve the monitoring, estimation and prediction of biomass in the boreal forest through remote sensing, knowledge of forest gap dynamics and simple empirical modelling that incorporates climate variables, as well as soil properties. The procedures are developed so as to be applicable to the boreal forest as a whole, a major departure from the traditional growth and yield models that are regional only in their domain of application. Early results of the work include simple Canada-wide biomass and growth and yield equations, remote sensing procedures to estimate standing stock in non-inventoried areas, as well as growth and yield procedures based on climate variables and photo-interpreted stand attributes. Further work is planned to incorporate remote sensing and gap dynamics, and eventually large-scale disturbance dynamics to provide landscape-level estimates of age since disturbance.

I.33: Variations in Global Terrestrial Primary Production and Evapotranspiration Observed by the Moderate Resolution Imaging Spectroradiometer (MODIS), 2000-2005

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The first Earth Observing System (EOS) satellite Terra was launched in December, 1999, and the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard began providing data in February, 2000. We now have a six-year 1-km terrestrial Gross (GPP) and Net (NPP) Primary Production dataset. We present the variations (seasonality and inter-annual variability) of GPP/NPP for North America from the latest Collection (C4.8) for 2000-2005. Validation results show that the C4.8 data have higher accuracy and quality than previous versions. Analyses of the variations in GPP/NPP show that GPP reflects the strong seasonality of photosynthesis in mid- and high-latitudes, the major contributors to global GPP seasonality. Inter-annual variability in MODIS NPP for 2000-2005 reveals the negative effects of major droughts on carbon sequestration at the regional and continental scales.

Evapotranspiration (ET) is an important land surface process linking ecosystem carbon and water cycles. We have modified a Penman-Monteith algorithm to estimate ET (0.5-deg resolution) for North America using MODIS remote sensing data and global meteorological data. Tested at 21 AmeriFlux eddy covariance tower sites, our algorithm shows good agreement with site data. Estimates of seasonal and annual ET (2000-2005) show reasonable spatial patterns, with high ET corresponding to areas with high precipitation and high productivity, although there are differences resulting from differing climatic controls on carbon versus water fluxes. ET increases across most of North America, while decreasing in most of the rest of the world during this time period, affecting agricultural yield and water resources.

I.34: Global Representativeness of the AmeriFlux and Fluxnet Networks

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Presented will be the results of two global network analyses. First, a greyscale map showing the global representativeness of the AmeriFlux network will show, in a quantitative fashion, how well the constellation of AmeriFlux sites represents all of the terrestrial environmental conditions on Earth. Second, a greyscale map showing the global representativeness of the entire FluxNet network will show how well all of the existing eddy flux sites represent the global environmental conditions. This analysis is based on 14 topographic, soil, and climate variables included at 2 arc min (about 4km at the equator). These factors were 1) Shuttle Radar Topography Mission (SRTM) elevation, 2) Compound Topographic Index (CTI), 3) solar flux, 4) potential available water capacity, 5) soil bulk density, 6) total soil carbon, 7) total soil nitrogen, 8) bio-temperature, 9) diurnal temperature range, 10) moisture stress, 11) precipitation of the driest quarter, 12) precipitation of the wettest quarter, 13) temperature of the coolest quarter, and 14)

temperature of the warmest quarter. These maps, and the analysis technique itself, are likely to be of interest in understanding how well carbon flux measurements represent flux globally and in planning additions or alterations to the North American network of flux towers or planning for field campaigns like the Mid-continent Intensive.

I.35: Perpetual Growth or Potential Catastrophic Dieback of North American Forests?

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The MAPSS team participated in the VINCERA (Vulnerability and Impacts of North American forests to Climate: Ecosystem Responses and Adaptation) project. VINCERA was designed to intercompare three dynamic general vegetation models (DGVMs) over most of North America using three General Circulation Models (GCMs), each of which simulated future climate under two different greenhouse gas emissions scenarios. The comparison between two of the DGVMs, MC1 and SDGVM, will be presented. The two DGVMs behaved similarly over 100 years of historical climate, but diverged dramatically under all future scenarios. SDGVM simulated increased productivity and carbon sequestration through 2100. MC1 originally showed increases, but then simulated dramatic declines in most forested ecosystems. The differences are due to minor uncertainties (< 1%) in large fluxes of carbon going in to and coming out of ecosystems. The primary uncertainties accounting for the differences between the two models are in 1) the relative strength of the effects of elevated CO2 concentration on plant water-use-efficiency and productivity and 2) in the approach to simulating wildfire. Increasing the strength of the CO2 effect in MC1 (via a beta function) significantly mitigated the carbon losses under the future climate scenarios. However, the simulation of wildfire in MC1 had to be nearly completely subdued in order to bring the two models into near parity. Under some future scenarios, in the absence of fire suppression/exclusion, much of the eastern U.S. forest and the southern reaches of the Boreal Forest are converted to non-forest under catastrophic disturbance.

I.36: A high-resolution daily surface weather database for NACP investigations

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Work is underway to produce a database of daily surface weather fields at high resolution (1 km) over all of North America, suitable for use in driving forward (prognostic) models of terrestrial ecosystem processes. The database includes daily maximum and minimum temperature, daily total precipitation, daily average water vapor pressure, and incident shortwave radiation. A major challenge for this effort is the acquisition and integration of existing datasets from Mexico, Canada, and the United States. Here we describe preliminary efforts to integrate several large subsets of the international data sources. We also outline the requirements for a complete integration and describe the benefits to a Joint NACP effort.

Carbon Management and Decision Support

J.1: Linking Landscape-Scale Carbon Monitoring with Forest Management

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We are integrating intensive ground-based measurements, remote sensing, and modeling at seven landscape-scale research sites across the U.S. to estimate carbon stocks and fluxes for forest carbon pools. As part of the North American Carbon Program, this study is intended to tie the spatially extensive, but coarsely resolved, measurements made

through remote sensing and forest inventory to the spatially intensive and highly resolved measurements made at intensive monitoring sites such as the AmeriFlux network. Each study site consists of a diverse landscape that reflects the effects of natural disturbances and/or forest management activities on carbon stocks and productivity. To demonstrate the relevance of this work to land managers, we are evaluating how this information can improve decision support tools for estimating and reporting carbon stocks and changes in carbon stocks. The main products of this research include precise statistical estimates and maps of carbon stocks and productivity for a variety of forest landscape conditions; improved process models at ecoregion and stand scales; and decision-support tools for land managers interested in carbon management. We will estimate NPP and NEP for managed or disturbed tree stands in various stages of development, which will improve the ability of land managers to update or project stand-level inventories of carbon stocks for project evaluation and reporting to greenhouse gas registries. Reference data from these sites can be used by the scientific, policy, and land management communities. If successful, this project may evolve into a larger network of landscape-scale monitoring sites.

J.7: SOCCR: The State of the Carbon Cycle Report; U.S. Climate Change Science Program Synthesis and Assessment Product 2.2

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The first State of the Carbon Cycle Report (SOCCR), The North American Carbon Budget and Implications for the Global Carbon Cycle, is scheduled for release as U.S. Climate Change Science Program Synthesis and Assessment Product 2.2 in March 2007. The two broad objectives for SOCCR and CCSP SAP 2.2 are: (1) to summarize scientific knowledge about carbon cycle properties and changes, and (2) to provide scientific information for decision support and policy formulation concerning carbon. The report summarizes knowledge and uncertainties about the carbon cycle in Canada, the United States, and Mexico relevant to North America and the rest of the world. In a format useful to decision makers, it provides scientific information for decision support focused on key issues for carbon management and policy. The report addresses carbon emissions, natural carbon cycling on land and in coastal oceans, and options to manage emissions and carbon sequestration. The report is a community effort with more than 75 scientific authors for the U.S., Canada and Mexico and actively engaging a broad spectrum of decision makers through a series of workshops. We briefly summarize the near final content of the draft report and describe the project's experience with integrating scientific assessment and stakeholder interests

J.8: Decision Support Tools and Data Analysis for Ecosystem Carbon Management in the United States

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Ecosystem modeling and satellite remote sensing are being used in combination to assess activities such as land use change and afforestation on carbon pools and fluxes across the United States. An internet-based decision support tool called CASA-CQUEST (Carbon Query and Evaluation Support Tools), has been developed for carbon management in U. S. ecosystems. Using the NASA-CASA model for predictions of regrowth forest production, a conservative national projection of 0.3 Pg C is reported as potential carbon stored each year through afforestation on relatively low-production crop or rangeland areas. Afforestation at this level of intensity has the capacity to offset at least one-fifth of annual fossil fuel emission of carbon in the United States. These projected afforestation carbon gains also match or exceed recent estimates of the annual sink for atmospheric CO2 in currently forested area of the country.

J.11: Particularities of urbanization, sustainability and carbon emissions in Latin American cities

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This paper presents the result of research on carbon management in Mexico and other Latin American countries, undertaken under both the Global Carbon Project (GCP) activity "Urban and Regional Carbon Management" (URCM), and the Mexican Carbon Program (PMC). The paper discusses ecological modernization theory and the notions of eco-city and ecological cities that dominate the discourse on how to reduce greenhouse gas emissions in cities. Ecological modernization focuses primarily on technological approaches supported by market mechanism to curb carbon emissions. The paper presents three sets of reasons why these approaches are not applicable to Latin American cities. The first refers to urbanization, which belongs to one of the global trends altering the carbon cycle and other biogeochemical processes. Yet urbanization has followed specific development pathways in Latin America (and other middle and low income areas), with diverse consequences for net regional and global carbon balances). Secondly, Latin American cities are not big emitters, in comparison to cities in high-income nations; rather than climate change, the health implications of air-quality are the main concern for local authorities. Curbing carbon emissions may be only "localized" when it can be linked to pressing issues (e.g. air quality) already on the local agenda. Finally, the specific socioeconomic and institutional conditions of Latin America strongly constrain the feasibility of the governance model implied in both ecological modernization and the notions of "eco-cities" and "ecological cities".

Reconciling Top-Down and Bottom-Up Approaches to Estimating Carbon Fluxes

K.15: Tracking the Carbon Oxidation State and Oxidative Ratio of the Terrestrial Biosphere

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We are developing a range of techniques to measure the carbon oxidation state (C_{ox}) of the Earth's major active carbon reservoirs: the above-ground terrestrial biosphere, soils, and ocean sediments. C_{ox} is a fundamental Earth system parameter, providing information on the processes of carbon fixation and degradation. C_{ox} can range from -4 (CH_4) to +4 (CO_2), with most solid and liquid carbon pools having values ranging from -2 to +1.

Understanding shifts in the terrestrial biospheric C_{ox} is important because C_{ox} is closely related to ecosystem oxidative ratio (OR), defined as the moles of O_2 released per moles of CO_2 fixed. The oxidative ratio (OR) of the terrestrial biosphere is a key component in O_2-based calculations of the biosphere's uptake of fossil fuel CO_2 (eg [Keeling, et al., 1996]). Ecosystem OR has been assumed to be invariant; however, small OR variations may cause significant shifts in the calculated size of the terrestrial biospheric C sink [Randerson, et al., 2006]. Accurate measurements of C_{ox} and its derived variable, OR, are necessary for the accurate apportionment of fossil fuel CO_2 between the atmosphere, oceans, and terrestrial biosphere.

C_{ox} can be measured via a number of techniques. We have successfully measured C_{ox} via elemental analysis, nuclear magnetic resonance, and calorimetry, and are currently testing x-ray photoelectron spectroscopy. Each of these techniques is matrix-sensitive, and more than one technique is currently necessary to measure the C_{ox} of an entire ecosystem. Our measurements indicate that terrestrial biospheric C_{ox} values are about 0±0.5, concordant with our understanding that the chemical composition of the terrestrial biosphere is dominated by cellulose (C_{ox} = 0), lignin (C_{ox} = -0.33), and other biological compounds (organic acids, amino acids, and lipids), whose C_{ox} values range broadly.

Keeling, R. F., et al. (1996), Global and hemispheric CO_2 sinks deduced from changes in atmospheric O_2 concentration, Nature, 381, 218-221.
Randerson, J. T., et al. (2006), Is carbon within the global terrestrial biosphere becoming more oxidized? Implications for trends in atmospheric O_2, Global Change Biology, 12, 260-271.

K.16: Constraining North American Fluxes of Carbon Dioxide and Inferring their Spatiotemporal Covariances through Assimilation of Remote Sensing and Atmospheric Data in a Geostatistical Framework

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This poster presents preliminary work from a new project which will use remote-sensing data and atmospheric measurements in a geostatistical inverse modeling framework to quantify North American surface fluxes of carbon dioxide at high spatiotemporal resolution. The proposed approach will estimate the magnitude of these fluxes without relying on prior flux estimates, and will account for the uncertainties and covariances associated with measurement and transport errors and flux distributions. In addition, we will evaluate the influence of remote-sensing derived auxiliary environmental data on flux estimates. This approach will enable more accurate flux accounting and will also provide process-based understanding of flux variations. This process- based understanding will be useful when compared to biospheric model parameterizations. Preliminary results using real atmospheric data suggest that LAI, FPAR, and synoptic scale meteorological parameters explain a significant amount of biospheric flux variability at the global scale. Synthetic data experiments using a repeating monthly-mean diurnal flux cycle at the scale of North America show that the technique is able to accurately recover monthly average NEE and the monthly- average diurnal cycle of NEE for large portions of the continent at 1° × 1° resolution.

Data Systems/Management

M.1: NACP Data Center for Modeling and Synthesis

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The North American Carbon Program (NACP) is designed to quantify the magnitudes and distributions of carbon sources and sinks, explain the processes controlling them, and

produce a consistent analysis of North America's carbon budget. To accomplish these ambitious goals, NACP requires an integrated data and information management system that will enable researchers to access, understand, use, and analyze large volumes of diverse data at multiple thematic, temporal, and spatial scales.

The Modeling and Synthesis Thematic Data Center (MAST-DC) is an integral component of the NACP data system and will support NACP by providing data products and data management services needed for modeling and synthesis. The overall objective of MAST-DC is to provide advanced data management support to NACP investigators and agencies performing modeling and synthesis activities. Based on specific requirements established by NACP, we will provide data products for modeling and synthesis in consistent and uniform grids, projections, and formats.

The specific tasks of MAST-DC are (1) coordinate data management activities with NACP modelers and synthesis groups; (2) prepare and distribute model input data; (3) provide data management support for model outputs; (4) provide tools for accessing, subsetting and visualization; (5) provide data packages to evaluate model output; and (6) support synthesis activities, including data support for workshops. MAST-DC will provide data products and services required by NACP in a central location, with common and co-registered spatial projection, in easily converted formats.

The MAST-DC will free modelers and those doing the synthesis and integration from having to perform data management functions. Consequently the MAST-DC will enable NACP participants to conduct their work more readily, facilitate the development of new model products needed by models, and assist in gaining new insights into the carbon cycle in North America.

M.2: Enhancing Linkages Between Projects and Datasets: Examples from LBA-ECO for NACP

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The Carbon Cycle and Ecosystems Office is developing ideas to build a warehouse of metadata resulting from the North American Carbon Program. The resulting warehouse and applications would be very similar to those developed for the LBA-ECO Project (www.lbaeco.org). The harvested metadata would be used to create dynamically generated reports, available at www.nacarbon.org, which would facilitate access to NACP datasets.

Our primary goal is to, as much as possible, associate harvested metadata with its corresponding project group profile. This also addresses high-priority goal #4 of the NACP Data System Task Force to "link the dataset metadata index with the project metadata index generated and maintained by the NACP Office"[1]. The benefit of achieving this goal will be the maximization of data discovery by association of each dataset with its corresponding NACP project group profile. This provides a greater understanding of the scientific and social context of each dataset. This will be challenging, because the datasets exist in many different formats, residing in many thematic data centers and also distributed among hundreds of investigators. Among other things, this situation creates a lack of consistency in how associated metadata is composed, thereby limiting our ability to fully automate metadata harvesting as well as dynamic generation of a wide variety of associated reports.

Our presentation will give a brief technical overview of how we plan to harvest the metadata. We currently only harvest metadata that is in an XML format. However, not all NACP datasets have corresponding metadata in XML. Therefore, we will need to expand upon our current capabilities by creating harvest and ingest scripts that can extract metadata in other formats.

We will also demonstrate what we can do for NACP by looking at what we have already done for LBA-ECO. For example, the LBA-ECO website (www.lbaeco.org) provides a profile (e.g. participants, abstract(s), study sites, and publications) for each LBA-ECO investigation. These profiles are very similar to the NACP project profiles. Linked from each profile is a list of associated registered dataset titles, each of which link to a dataset profile that describes the metadata in a user-friendly way. Moreover, each dataset profile contains hyperlinks to each associated data file at its home data repository and to publications that have used the dataset.

We also use the harvested metadata from the LBA Project in administrative applications to assist quality assurance efforts. These include processes to check for broken hyperlinks to data files, automated emails that inform our administrators when critical metadata fields are updated, dynamically generated reports of metadata records that link to datasets with questionable file formats, and dynamically generated region/site coordinate quality assurance reports. These applications are as important as those that facilitate access to information because they help ensure a high standard of quality for the information. Where possible, we hope to create similar reports for NACP.

[1] *Prioritized list of recommendations to CCIWG regarding NACP Data Central, NACP Data System Task Force, July 24, 2006.*

M.3: NACP Project Profiles: Enhancing communication among scientists and agency managers

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The NACP website provides a profile for each core and affiliated NACP project. This profile includes information such as the project's title, participants, an abstract, keywords,

funding agencies, associated intensive field campaigns, and URLs to associated data centers, datasets, and metadata. By making this information easily and publicly available on our website, the NACP Project profiles become an important means of communicating the following to the larger carbon cycle science community:

1. Who are the NACP core and affiliated projects.
2. What specifically are these projects doing for NACP.
3. Who is participating in the projects.

To facilitate the creation and maintenance of accurate information, this presentation will step project leads through the process of submitting and updating an NACP project profile. It will discuss the various tasks that can be accomplished with the NACP Project Profile update tool. It will also discuss in detail the information that is displayed in the project profiles. Additionally, we will discuss future plans for profile search tools, answer questions about the submission process, and solicit feedback for additions and improvements to our existing profile infrastructure.

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Stoy, Paul	B.26
Strahler, Alan	B.32, **B.33**

Strand, Allan E	E.7
Striegl, Robert	F.7
Sturtevant, Brian R	E.9
Styles, Julie M	H.12
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Subramaniam, Ajit	C.14
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Sun, Jiangfeng	F.13
Sundquist, Eric T.	**I.24**, I.25
Sutton, Paul	L.1
Suyker, Andrew E.	B.36
Swanston, Chris	B.12
Swanston, Christopher W	B.15
Swenney, Colm	A.11, **A.12**, A.7, C.12, I.2, I.9, K.11
Takahashi, Taro	C.15
Takle, Eugene	I.20
Tan, Zhengxi	**H.14**, J.3
Tang, Jianwu	D.4
Tans, Pieter P.	A.11, A.12, A.4, A.7, I.2, I.9, K.11
Teclaw, Ronald M	D.4
Thomas, R Quinn	**B.34**
Thompson, Michael L	**B.4**
Thomson, Allison M.	H.30
Thornton, Peter E.	**I.26**, **I.36**, **K.10**, M.1
Tian, Hanqin	**H.26**
Tieszen, Larry L.	H.27, J.2, J.3

Tieszen, Lawrence L.	F.7
Toon, Geoff	A.14
Torn, Margaret S	I.28, I.37, **K.11**
Torn, Margaret S.	B.12
Townsend, Philip A	**E.9**
Townshend, John	I.13, I.14
Trumbore, Susan E.	B.12, B.13, H.6
Tsay, Si-chee	I.13
Turetsky, Merritt R.	F.11, **F.14**, F.3
Turnbull, Jocelyn	A.11
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Tuttle, Benjamin T.	L.1
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Uliasz, Marek	A.16, A.3, D.2, K.14
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Urbanski, Shawn P.	B.24, I.5
Uz, Stephanie	C.14
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Vandemark, Douglas	C.10, C.9
Varner, Ruth K	**B.35**, C.10
Vay, Stephanie	K.1
Vay, Stephanie A.	**A.13**
Verma, Shashi B.	**B.36**, B.9
Vierling, Lee	A.17, A.8
Vina, Andres	B.9
Vogel, Christoph S	A.17, A.8, E.1
Vorosmarty, Charles	I.8
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Voulgaris, George	G.3
Vugteveen, Timothy	B.20
Walker, Sarah	**J.9**
Walker, Wayne S	I.11
Walter-Shea, Elizabeth A.	B.36
Walters, Daniel T.	B.36
Wang, Dongdong	I.13
Wang, Jih-Wang	A.9
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Wanninkhof, Rik H	**C.13**, C.2
Washenfelder, Rebecca	A.14
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Watson, Tom	K.6
Watt, Andrew	A.6
Watts, Christopher J	**B.46**
Wayson, Craig A.	**B.37**, H.25
Weishampel, Peter	**B.17**, J.1
Wennberg, Paul O	A.14, K.12
West, Tristram O.	B.20, **D.7**, **I.27**
Westfall, James	I.11
Whitcomb, Jane	**F.6**
White, Michael A.	I.17
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Wielopolski, Lucian	**B.38**, **B.47**, **H.28**
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