B42A MCC: Level 2 Thursday 1330h

Human Interactions, Biomass Removal, and the Carbon Cycle Posters *(joint with A, H, OS, GC, PA)*

Presiding: **R Follett,** USDA Agricultural Research Service**; L Dilling,** National Center for Atmospheric Research

B42A-0931 1330h POSTER

Carbon Management and Decision Support Systems for the CASA Ecosystem Model

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Ecosystem modeling and satellite remote sensing can link human activities such as land use change and forest management to the spatial distribution of carbon pools and fluxes at regional scales. The main objectives of this research and application are to: 1) evaluate major forest and agricultural sinks of atmospheric carbon dioxide in the U. S. using NASA EOS satellite data and ecosystem modeling, 2) support the U. S. Government interagency program for registration of voluntary greenhouse gas emissions reductions under section 1605(b) of the 1992 Energy Policy Act, and 3) develop an internet-based decision support system (DSS) of carbon sequestration in U. S. ecosystems for users nationwide. We report on the first results of this DSS to assess the impacts of forest stand age on potential carbon sequestration, as predicted by the CASA (Carnegie Ames Stanford Approach) biosphere model. Estimates of carbon storage in woody plant pools are compared before and after adjustment for management of stand age based on U. S. Forest Service map products. These predictions of historical forest carbon storage are subsequently compared to the potential annual increment of ecosystem carbon gain or loss under conditions of future climate variation.

URL: http://geo.arc.nasa.gov/sge/casa/cquest.html

B42A-0932 1330h POSTER

Residue Removal Affects the Carbon Content of No-Till Soils

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No-till crop management often results in increased soil organic carbon contents. However, the effect of residue removal for fuel or animal fodder on soil carbon content is not well understood, especially with no-till management practices. We utilized a multiyear study at six locations in central Mexico, with a wide range of soil and climatic conditions to determine the effect of varying rates of residue removal and no-till management on soil carbon content. Treatments consisted of annual moldboard plowing and no-till management practices with 100%, 67%, 33% and none of the corn (Zea mays) crop residue retained on the no-till soil surface. Even when all crop residues were removed, no-till practices maintained carbon levels above that of moldboard plowing at five of the six locations. Retaining crop residues affected the soil carbon content differently depending on climatic conditions. Retaining crop residues on the soil surface increased soil carbon content at a much faster rate in cool conditions than in warm tropical conditions. Carbon content was greater in regions with higher amounts of rainfall than in drier regions. Retaining crop residues on the soil surface with no-till will usually increase soil carbon content, but climatic conditions should be considered to determine if crop residue would be more effectively utilized for energy production or animal fodder.

B42A-0933 1330h POSTER

Effects of Cover Crops to Offset Soil Carbon Changes Under No-till on an Ohio farm when Biomass is Harvested

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The results of a long term experiment to look at the use of cover crops and there effect on soil organic carbon. No-till has been shown to increase SOC and improve the overall soil quality under conditions where the biomass has been returned to the field. However, biomass may be removed as silage or for use in biofuels. The removal will reduce the inputs to the field so to overcome the amount of biomass not returned to the soil different cover crops were used. This experiment was done on a working farm where the corn biomass was being removed as silage. Four cover crops were planted in early September of 2002: rye, oats, clover, and canola with two controls, one with no cover crop and one where corn stubble was left on the field. The soils were sampled soon after the crops were planted and again in the spring of 2003 before the cover crops were killed just prior to planting. The first results indicate that the most root biomass was produced by the rye followed by oats then canola and then clover.

B42A-0934 1330h POSTER

Estimates of Fossil Fuel Carbon Dioxide Emissions From Mexico at Monthly Time Intervals

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Human consumption of fossil fuels has greatly contributed to the rise of carbon dioxide in the Earth's atmosphere. To better understand the global carbon cycle, it is important to identify the major sources of these fossil fuels. Mexico is among the top fifteen nations in the world for producing fossil fuel carbon dioxide emissions. Based on this information and that emissions from Mexico are a focus of the North American Carbon Program, Mexico was selected for this study. Mexican monthly inland sales volumes for January 1988-May 2003 were collected on natural gas and liquid fuels from the Energy Information Agency in the United States Department of Energy. These sales figures represent a major portion of the total fossil fuel consumption in Mexico. The fraction of a particular fossil fuel consumed in a given month was determined by dividing the monthly sales volumes by the annual sum of monthly sales volumes for a given year. This fraction was then multiplied by the annual carbon dioxide values reported by the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory (ORNL) to estimate the monthly carbon dioxide emissions from the respective fuels. The advantages of this methodology are: 1) monthly fluxes are consistent with the annual flux as determined by the widely-accepted CDIAC values, and 2) its general application can be easily adapted to other nations for determining their sub-annual time scale emissions. The major disadvantage of this methodology is the proxy nature inherent to it. Only a fraction of the total emissions are used as an estimate in determining the seasonal cycle. The error inherent in this approach increases as the fraction of total emissions represented by the proxy decreases. These data are part of a long-term project between researchers at the University of North Dakota and ORNL which attempts to identify and understand the source(s) of seasonal variations of global, fossil-fuel derived, carbon dioxide emissions. Better knowledge of the temporal variation of the annual fossil fuel flux will lead to a better understanding of the global carbon cycle. This research will be archived at CDIAC for public access.

B42A-0935 1330h POSTER

Biomass Production and Soil Carbon Level Changes in Various Tillage, Residue Management, and Cropping Systems in Moderately High Organic Matter Soils in Eastern South Dakota, U.S.A.

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A four-year replicated field study was conducted in eastern South Dakota to assess the impact of maize (Zea mays L.), soybean (Glycine max L.), and spring wheat (Triticum aestivum L.) on crop residue accumulation and soil carbon when various tillage, crop residue management, and crop rotation scenarios were applied. Before planting, half the plots were chisel plowed and harrowed (tilled vs. no-till treatments). Corn-soybean, soybean-wheat, or corn-wheat-soybean rotations were established (rotation treatments). After grain harvest, crop residues were removed on half of the plots (residue-removed vs. residue-retained treatments). The range of initial soil carbon levels (loss by ignition method) for the 0-15cm depth was 1.7-3.0%. Post-harvest crop residue accumulation was greatest for the residue-retained treatment compared to the residue-removed treatment and for the no-till treatment compared to the tilled treatment. In addition, surface biomass accumulation was greatest when maize was part of a crop rotation. Maize can produce greater levels of biomass compared to either spring wheat or soybean. The least surface biomass accumulation was measured in the soybean-wheat rotation.

B42A-0936 1330h POSTER

A Method for Improving Temporal and Spatial Resolution of Carbon Dioxide Emissions

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Using United States data, a method is developed to estimate the monthly consumption of solid, liquid and gaseous fossil fuels for each state in the union. This technique employs monthly sales data to estimate the relative monthly proportions of the total annual national fossil fuel use. These proportions are then used to estimate the total monthly carbon dioxide emissions for each state. To assess the success of this technique, the results from this method are compared with the data obtained from other independent methods. To determine the temporal success of the method, the resulting national time series is compared to the model produced by Carbon Dioxide Information Analysis Center (CDIAC) and the current model being developed by T. J. Blasing and C. Broniak at the Oak Ridge National Laboratory (ORNL). The University of North Dakota (UND) method fits well temporally with the results of the CDIAC and current ORNL research. To determine the success of the spatial component, the individual state results are compared to the annual state totals calculated by ORNL. Using ordinary least squares regression, the annual state totals of this method are plotted against the ORNL data. This allows a direct comparison of estimates in the form of ordered pairs against a one-to-one ideal correspondence line, and allows for easy detection of outliers in the results obtained by this estimation method. Analyzing the residuals of the linear regression model for each type of fuel permits an improved understanding of the strengths and shortcomings of the spatial component of this estimation technique. Spatially, the model is successful when compared to the current ORNL research. The primary advantages of this method are its ease of implementation and universal applicability. In general, this technique compares favorably to more labor-intensive methods that rely on more detailed data. The more detailed data is generally not available for most countries in the world. The methodology used here will be applied to other nations in the world to better understand their sub-annual cycle and sub-national spatial distribution of carbon dioxide emissions from fossil fuel consumption. Better understanding of the cycle will lead to better models used for predicting and responding to global environmental changes currently observed and anticipated.

B42A-0937 1330h POSTER

Modeling the CO_2 and N_2O Emissions From Stover Removal for Biofuel Production From Continuous Corn Production in Iowa

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Corn stover, an agricultural residue, can be used as feedstock for near term bioethanol production and is available today at levels that can significantly impact energy supply. We evaluated the environmental impact of such a large-scale change in agricultural practices on green house gas production, soil erosion and soil carbon using the Century model. Estimates of soil C changes and GHG emissions were performed for the 99 counties in Iowa where previous environmental, management and erosion data was available. We employed climate, soil and historical management databases from a separate USDA-funded project as input to Century. RUSLE estimates of the residue requirements for acceptable soil loss rates under continuous corn agriculture were available from a previous study done Dr. Richard Nelson (Enersol Resources). Two mulch tillage and a no-till systems, where erosion estimates were available, were used as the basis for the simulations. Century simulations of these systems were run under a variety of stover removal rates. For each soil type within each county the model was run for 15 years (1980-1995) under continuous corn with convention tillage, and full residue return. Model simulation of crop yields and residue production were then calibrated to match those used by the Polysys model team at Oak Ridge and the simulation was repeated with the addition of the three corn tillage regimes, and several residue removal rates. County-average soil C changes (and net CO_2 emissions) were calculated as area-weighted averages of the individual soil types in each county. For this study, we have utilized the IPCC approach to estimate annual N_2O emissions. At low or zero residue removal rates, county-averaged soil C stocks were predicted to increase (i.e. net CO_2 emissions are negative). Where the allowable residue removal rates (based on erosion tolerance) for mulch-tillage are on the order of 40-50% or more, the reduced input of C is such that the soils no longer sequester C and become a net source of CO_2. Estimates of N_2O emissions from soil ranged from 1.4 to 2.8 kg N_2O-N ha^{-1} yr^{-1} across all counties, tillage systems and residue removal rates. The magnitude of these values is consistent with direct measurements of N_2O flux.

B42A-0938 1330h POSTER

Remote sensing for forest resource assessment: applications to carbon management

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The U.S. Forest Service and the State of Maryland's Department of Natural Resources have initiated an assessment of forest resources in Maryland, and across the Chesapeake Bay Watershed. This Strategic Forest Lands Assessment (SFLA) uses remote sensing and geographic information systems analyses to conduct ecological, socioeconomic and vulnerability assessments in support of resource management activities and forest product based economies. As part of this activity we are modeling net primary productivity of the region, and producing maps of land cover type - including the proportion of subpixel tree cover from Landsat7 imagery. These map products are being used in several programs to assess forest cover change, relationships with standing carbon stocks, and to target lands for a combination of ecological protection and economic resource extraction, as well as carbon sequestration. These efforts not only provide critical data sets and derived products used as decision tools for forest conservation, restoration and enhancement, but also advance efforts to promote sustainable forestry activities. The forest management efforts are designed to optimize carbon sink strategies and reduce atmospheric carbon pools. By using a combination of estimated, simulated and measured biomass and productivity, and timber removal estimates from Forest Inventory Analysis, we can determine where carbon sequestration can be maximized and sustainable forestry activities can be encouraged. The effects of these forest management activities, both past and present, and changes in forest cover, can have substantial impacts on regional carbon sequestration.

B42A-0939 1330h POSTER

Quantifying Contemporary Terrestrial Carbon Sources and Sinks in the Conterminous United States

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U.S. land likely accounts for a significant portion of the unidentified global carbon sink, although the magnitude is highly uncertain. The ultimate goal of this study is to quantify the contemporary temporal and spatial patterns of carbon sources and sinks in the conterminous United States from the early 1970s to 2000, and to explain the mechanisms that cause the variability and changes. Because of the difficulty and massive cost for developing land cover change databases for the conterminous United States, we adopt an ecoregion-based sampling approach. Carbon dynamics within thousands of 20 km by 20 km or 10 km by 10 km sampling blocks, stratified by Omernik Level III ecoregions, are simulated using the General Ensemble Biogeochemical Modeling System at the spatial resolution of 60 m by 60 m. The land use change data, providing unprecedented accuracy and consistency, are derived from Landsat imagery for five time points (nominally 1972, 1980, 1986, 1992, and 2000). Mechanisms have been implemented to assimilate data from key national benchmark databases (including the USDA Forest Service's Forest Inventory and Analysis data and the USDAs agricultural census data). The dynamics of carbon stocks in vegetation, soil, and harvested wood materials are quantified. Results from three ecoregions (i.e., Southeastern Plains, Piedmont, and Northern Piedmont) indicated that the carbon sink strength has been decreasing from the 1970s to 2000. The relative contribution of biomass accumulation to the sink decreased during this period, while those of soil organic carbon and harvested wood materials increased.

B42A-0940 1330h POSTER

Soil Carbon Budget During Establishment of Short Rotation Woody Crops

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Carbon budgets were monitored following forest harvest and during re-establishment of short rotation woody crops. Soil CO_2 efflux was monitored using infared gas analyzer methods, fine root production was estimated with minirhizotrons, above ground litter inputs were trapped, coarse root inputs were estimated with developed allometric relationships, and soil carbon pools were measured in loblolly pine and cottonwood plantations. Our carbon budget allows evaluation of errors, as well as quantifying pools and fluxes in developing stands during non-steady-state conditions. Soil CO_2 efflux was larger than the combined inputs from aboveground litter fall and root production. Fineroot production increased during stand development; however, mortality was not yet equivalent to production, showing the belowground carbon budget was not yet in equilibrium and root carbon standing crop was accruing. Belowground production was greater in cottonwood than pine, but the level of pine soil CO_2 efflux was equal to or greater than that of cottonwood, indicating heterotrophic respiration was higher for pine. Comparison of unaccounted efflux with soil organic carbon changes provides verification of loss or accrual.

B42A-0941 1330h POSTER

Soil Quality as Affected by Biomass Removal in Tallgrass Prairie

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Perennial grasses have been proposed as a source for bioenergy. However, the impact of biomass removal on long-term soil quality needs to be assessed. Soil C and N storage and soil aggregate stability may be used as indicators of soil quality. Long-term experimental tallgrass prairie plots, located at Konza Prairie Biological Station in the flinthills of Eastern Kansas were used to examine soil quality following 16 years of experimental treatments. These plots use burning and mowing for biomass removal, and include nitrogen addition as an additional management practice. These sites are dominated by warm-season C4 grasses (switchgrass, big bluestem, and indian grass). Biomass removal by mowing did not affect aboveground productivity of the dominant grasses. However, annual burning and N addition each increased productivity. In soil collected from 0-5 cm depth, N fertilization increased both soil organic C and N, and increased the proportion of macroaggregates, with a concomitant decrease in microaggregates. Higher organic C and N were observed in both macro- and microaggregate fractions. Burning (annually, early spring) had no effect on soil C in the surface 5 cm, but decreased soil N and increased macroaggregate formation, as compared to corresponding unburned plots. Mowing (in late June), decreased soil C but did not influence soil aggregate formation. Overall, a strong correlation was observed between mycorrhizal hyphal development and aggregate stability, indicating that these fungi may play an important role in soil aggregate formation. Proper management of prairie grasses for bioenergy could sustain soil quality.

B

B42A-0942 1330h POSTER

Total Carbon and Nitrogen Budget in Pasture Soils After 10 Years of Elevated CO_2

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The impact of elevated CO_2 and N-fertilization on soil C-cycling in *Lolium perenne* and *Trifolium repens* pastures were investigated under Free Air Carbon dioxide Enrichment (FACE) conditions. For ten years, swards were exposed to ambient or elevated CO_2 (35 and 60 Pa p CO_2) and received a low and high rate of labeled (^{15}N) N fertilizers. The CO_2 added in the FACE plots was depleted in ^{13}C compared to ambient (δ ^{13}C -40 per mille) thus the C and N inputs could be quantified. The maximum amount of labile C in the *T. repens* sward was estimated at 10.4$\pm$1.3 Mg ha^{-1} and 9.7$\pm$ Mg ha^{-1} in the *L. perenne* sward. Mean residence time (MRT) for newly sequestered soil C was estimated at 3.5 years for *T. repens* and 4.2 years for *L. perenne*. An average of 34 % and 7 % of total soil C in the 0-10 and the 10-25 cm depth respectively in the *T. repens* sward and 30 % and 8 % respectively in the *L. perenne* sward was derived from FACE after 10 years exposure. The majority of the change in soil δ ^{13} occurred in the first three years of the experiment. We found no treatment effect on total soil C and FACE derived C was not detected in the 50-75 cm depth layer. In the 0-10 cm depth, total N is similar under *L. perenne* and *T. repens* swards, regardless of CO_2 treatment. Whereas total ^{15}N under *T. repens* is smaller than under *L. perenne*, due to symbiotic atmospheric $^{14}N_2$ fixation in the legume *T. repens*. Leached ^{15}N was not observed in the 50-75 cm depth layer of all treatments. Although the rate of C and N cycling was affected by species, the soil in this intensively managed grassland ecosystem did not become a sink for additional C under elevated CO_2 conditions.

B42A-0943 1330h POSTER

Land Use Land Cover Change in the Albertine Region of Uganda

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Monitoring threats to protected areas and species is a major challenge for the conservation community. The Albertine Rift region is a hot spot of biodiversity with many endemic vertebrates and plant species. Most of forests east of the Albertine (Uganda, Rwanda and Burundi) are, however, highly fragmented and human population densities are some of the highest of Africa. In this study, we used a series of Landsat images to provide a quantitative assessment of forest loss between the 1980s to year 2000 for the protected areas in the Western Uganda. In this region, monitoring forest conversion to agricultural land and modeling future threats for the protected areas system are important to the maintenance of wildlife populations. By combining remote sensing monitoring techniques with traditional field surveys, it becomes easier to monitor and manage extensive protected area systems. Most of the forest loss (deforestation) was located outside the official protected area limits, indicating that active deforestation during this period is mainly located on non protected lands. The largest forest loss was located in the north around Bugoma, Budonga and Kagombe Forest Reserves and is associated with large scale farming and mechanized logging.

B42A-0944 1330h POSTER

Preliminary Net Carbon Exchange Measurements in the Nebraska Sand Hills

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The Nebraska Sand Hills are the largest stabilized dune field in the world; they cover more than 50,000 square kilometers. The native vegetation is classified as a mixed grass prairie and the most common land use is cattle grazing. The proximity of the High Plains Aquifer to the land surface in this area gives rise to areas of abundant soil moisture in the generally semi-arid climate. This leads to an uncoupling of vegetation dynamics (including net carbon exchange) and recent precipitation in much of the region. We will present preliminary results of net ecosystem carbon exchange from eddy covariance measurements and soil surface carbon dioxide fluxes determined using a chamber technique. Fluxes will be examined in terms of relevant environmental and biological paramenters.

B42A-0945 1330h POSTER

Process Based Belowground Carbon Dioxide Modeling in a Desert Ecosystem

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We describe a study to integrate and assess biological and physical processes that govern belowground carbon dioxide levels at a semi-arid grassland near Canyonlands National Park. Carbon dioxide concentrations were measured every 30 minutes at 5 and 15 cm depth within the rooting zones of the two dominant grass species, Stipa hymenoides and Hilaria jamesii, as well as the interspace between the two. For Stipa hymenoides at 5 cm, a rain event caused belowground carbon dioxide levels to rise from 600 ppm to 2000 ppm with a response time of 8 hours, with a gradual return to quasi-steady state levels in subsequent days. A similar response was observed for H. jamesii. We developed and simulated a one-dimensional diffusion model with a production term for various types of CO_2 production from the literature (either constant with increasing depth or a process based source). The process based production considered microbial and root respiration as well as the temperature dependence of soil respiration. Model inputs included volumetric soil water content, temperature and bulk density. Incorporating a process based production term led to high correlation between measured and modeled CO_2 concentrations (r^2 as high as 0.92). Our results indicate that carbon dioxide levels increased during rain events due to physical (not biological) processes as the soil saturated with water, and CO_2 molecules diffused more slowly from the soil.

B42A-0946 1330h POSTER

Quantifying the Uncertainties in the Carbon Content of the Terrestrial Biosphere

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According to the IPCC (2001), the 1980s estimates for all major terms in the global carbon budget are subject to uncertainties. However, uncertainties in land use changes and terrestrial sinks are the largest, up to 200%. Here, we quantify the uncertainties in regional land use emissions as well as net terrestrial flux over the period 1765-2000. Using the terrestrial carbon cycle component of the Integrated Science Assessment Model (ISAM) coupled with observed atmospheric CO2, temperature and precipitation data, the effects of different land cover data sets on the response of plant and soil carbon stocks are assessed. This geographically-explicit implementation of ISAM simulates the carbon fluxes to and from different compartments of the terrestrial biosphere with 0.5-by-0.5 degree spatial resolution. Each grid cell contains at least one of the thirteen land coverage classifications, which represent both highly managed land uses and less managed biomes. Changes in the areal extent of land cover classifications are driven by shifts in land use related to agriculture, afforestation, deforestation, and reforestation. Within each grid cell and land-coverage classification, the modeled carbon cycle includes feedback processes such as CO2 fertilization and temperature effects on photosynthesis, and respiration. ISAM model simulations indicate that uncertainties in net terrestrial fluxes during the 1980s is mainly due to the large uncertainties in land cover change data for tropical Africa and south and south east Asia.

B42B MCC: 3014 Thursday 1340h

Estimating Terrestrial Carbon, Water, and Energy Fluxes From Site to Region I *(joint with A, H)*

Presiding: **J Styles,** Oregon State University**; K J Davis,** Pennsylvania State University

B42B-01 1340h

Estimates of ABL-scale net carbon dioxide flux in Central Wisconsin

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The atmospheric boundary layer (ABL) is a distinct air mass separated from the free troposphere by a density inversion. The exchanges of sensible heat, water vapor and trace gases which occur at the land surface influence the properties of ABL air. While most studies of the ABL have focused on the dynamics of the diurnal cycle of ABL depth and on changes in trace gas concentration that occur over this time frame, it should be noted that the ABL can persist as a coherent structure over several days. Betts and Ridgeway (1989) and Betts (2000) proposed that the ABL during a sequence of fair weather days can be viewed as a steady-state structure forced on the one hand by surface exchanges and on the other by atmospheric subsidence coupled to the large-scale energy balance of the troposphere. Surface modified air in the ABL is replaced by air descending from areas of subsidence or high pressure, and this flow diverges to areas with storm activity. Given sufficient time, an equilibrium may establish such that the transport of flux by divergent flow balances the surface exchange fluxes. Under these conditions the flux of any trace gas, F_x is, $F_x = -\Delta X \times W$ where ΔX is the change in mixing ratio of X in the ABL relative to the free troposphere and W is the mean vertical velocity through the top of the ABL. We are specifically interested in using this relationship to calculate net carbon dioxide flux over the area of integration of the ABL from measurements of carbon dioxide mixing ratio made from a tall towers (that sample the ABL) and aircraft measurements (that sample the free troposphere). We describe two independent methods for resolving W at these temporal and spatial scales and show how these estimates, along with measurements of carbon dioxide gradients, can be used to estimate ABL-scale net carbon dioxide flux. Our estimates agree well with eddy-covariance based estimates of regional flux over monthly to annual periods.

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Regional CO_2 Fluxes Using a Network of Carbon Dioxide Mixing Ratio Sensors

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Inverse studies of CO_2 mixing ratio are traditionally conducted at coarse spatial and temporal resolution. This limits our ability to evaluate efforts to upscale chamber and stand level CO_2 flux measurements to regional scales, where coherent climate and ecosystem mechanisms govern the carbon cycle. We present an effort to implement atmospheric budget or inversion methodology on a regional scale. A first step towards this end is the evaluation of a network of six relatively inexpensive CO_2 mixing ratio measurement systems deployed on towers in northern Wisconsin as part of the Chequamegon Ecosystem-Atmosphere Study. Five systems are distributed on a circle of roughly 150-km radius, while one system is centrally located. All measurements are taken at a height of 76 m. The systems use LiCor-820 infrared CO_2 analyzers and are calibrated every two hours using four samples known to within $\pm$ 0.05 ppm CO_2. Field tests prior to deployment in which the six systems sampled the same air indicate agreement of the systems to within 0.5–1.0 ppm from the mean during relatively quiescent periods. Tests using tanks containing known CO_2 concentrations exhibit standard deviations of 1.0 ppm or less. If network precision and accuracy prove to be sufficiently high, these data will detect horizontal gradients in CO_2 mixing ratios caused by net ecosystem-atmosphere exchange. These horizontal gradients will be the basis for using atmospheric budget methods to derive regional fluxes with spatial and temporal resolution fine enough to warrant comparison to the ChEAS regional flux tower network. Results from the deployment (July–October 2003) are presented.