B51C-08 1045h INVITED

Mesoscale Modeling of Vegetation-Atmosphere Feedbacks

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The data collected as part of the Large-scale Biosphere Atmosphere (LBA) Experiment in Rondonia, Brazil and the data collected in central US as part of the GCIP program are used together with the Regional Atmospheric Modeling System (RAMS) to investigate the vegetation-atmosphere interactions at the different scales in these two different geographical locations. In both cases, the atmospheric boundary layer developing above various land covers is very different, sometimes creating horizontal pressure gradients strong enough to generate organized mesoscale circulations, which affect the structure of the boundary layer, clouds and precipitation. In a parallel investigation, three scenarios were produced with the Goddard Institute for Space Studies (GISS) GCM: (1) current climate using current land cover; (2) current climate with no deforestation in the Amazon basin; and (3) current climate with a mixture of pasture and brush in most of the Amazon basin. For each scenario, six realizations of 12-year runs were produced. Different statistical tests are used to demonstrate the effect of land-cover change in the Amazon on the regional climate of other continents. Particular attention is paid to the effects at the seasonal time scale. Teleconnections are clearly identified between the Amazon and North America, indicating that deforestation in the Amazon reduces the summer precipitation in central North America, and reduces fall precipitation in south-west North America.

B51C-09 1105h

Regional differences in carbon source-sink potential in the US

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We used the dynamic vegetation model MC1 to simulate the change in carbon storage potential under historical conditions (1895-1994) in the 6 regions of the conterminous USA delineated for the USGCRP National Assessment. The largest variations occur in the Midwest where large fire events (1937, 1988) affect vegetation biomass. The Southeast shows decadal-type trends and alternates becoming either a carbon source (1920's, 1940's, 1970's) or a sink (1910's, 1930's, 1950's). The drought of the 1930's is most obvious in the creation of a large carbon source in the Midwest and the Great Plains. The two most western regions and the northeast show the smallest amplitudes in their variations. Projections into the future using the CGCM1 climate scenario show the Northeast becoming mostly a carbon source, the Southeast becoming the largest carbon source in the 21st century, and the two westernmost regions becoming arbon sinks in the second half of the 21st century. Regional trends in C storage under historical conditions show an increase in soil organic matter with time except in the Midwest which starts loosing carbon in the 1900's but starts recovering it by the 1970's. The Pacific Northwest shows a less pronounced decline in soil C but that continues through the 1980's. Projections into the future show increases in soil organic matter in the Great plains and the two western-most regions, decreases in the Midwest and the Northeast,and a huge decline in the Southeast soil carbon levels with respect to the 1895 level.

B51C-10 1120h INVITED

Global and Regional Constraints on Exchanges of CO_2 Between the Atmosphere and Terrestrial Biosphere

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The vigorous atmospheric circulation rapidly mixes CO_2 that is exchanged with the terrestrial biosphere and oceans. Therefore, at time scales greater than 1 year, the approximate interhemispheric exchange time of the atmosphere, an average of CO_2 measurements from a network of surface stations can be used to accurately determine the global net change in atmospheric CO_2. By subtracting CO_2 produced by fossil fuel combustion, which is well characterized by national statistics, the global the sum of terrestrial biospheric and oceanic net fluxes, here termed the "nonfossil" CO_2 flux, can also be accurately determined. The nonfossil CO_2 flux averaged -2.1±0.3 PgC/yr and -3.2±0.4 PgC/yr in the 1980s and 1990s respectively (negative denotes out of the atmosphere), and varied in annual average from about 0 to -4 PgC/yr over these two decades.

Two primary methods have been used to further partition the nonfossil CO_2 flux between land and oceans: the O_2 and $^{13}C/^{12}C$ methods, which rely, respectively, on measurements of atmospheric O_2 (actually O_2/N_2 for technical reasons) and of the $^{13}C/^{12}C$ ratio of CO_2. Burning of fossil fuel consumes atmospheric O_2 and releases CO_2 with a $^{13}C/^{12}C$ ratio lower than that of atmospheric CO_2 whereas uptake of CO_2 by terrestrial plants releases O_2, and increases the atmospheric $^{13}C/^{12}C$ ratio owing to the preferential assimilation of $12CO_2$ relative to $13CO_2$. In contrast, the uptake of CO_2 by the oceans has little effect on either the atmospheric O_2 or $^{13}C/^{12}C$ ratio. Therefore, the net CO_2 uptake or release from the terrestrial biosphere can be calculated in either method by subtracting the change owing to fossil fuel emissions from the measured change in the atmosphere, utilizing known stoichiometric ratios of O_2 and CO_2 in the O_2 method, and isotopic fractionation factors in the $^{13}C/^{12}C$ method. Currently, the O_2 method gives a net global terrestrial biospheric CO_2 flux of -0.2±0.7 PgC/yr and -1.4±0.7 PgC/yr for the 1980s and the 1990s, respectively. Both the O_2 and $^{13}C/^{12}C$ methods have complications and limitations that will be discussed.

To partition the global biospheric flux further to zonal or regional detail or to shorter time steps, atmospheric models are required to simulate the transport of tracer from source regions to individual stations where air is sampled. An ongoing collaborative project to compare atmospheric models has highlighted significant differences in transport characteristics, mainly owing to differences in how the boundary layer is modeled. Accordingly, a recent compilation of model calculations showed a wide range of estimates for the tropical biosphere, from a significant release of CO_2 to an uptake over recent decades; however, the calculations showed reasonable agreement on a significant northern biospheric sink.

Fluxes of biospheric CO_2 can be determined accurately at the global scale as well as at individual sites. An ingenious blend of observations and models will be required to bridge the gap between these two extreme spatial scales, and thereby gain an understanding sufficient to predict the influence of the terrestrial biosphere on variations in atmospheric CO_2.

B51C-11 1135h

Modeling inter-annual variability at baseline CO_2 stations: Contributions from sources and transport

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Both the surface source variability and variability in atmospheric transport impact the observations of atmospheric CO_2 at baseline monitoring stations. Previously it was assumed that the contribution due to transport inter-annual variability was minor. Using the off-line tracer transport model MATCH (Model of Atmospheric Transport and Chemistry) and dynamics from the NCAR CCM2 (Community Climate Model) and the NCEP (National Centers for Environmental Prediction) reanalyses we demonstrate that the contribution of transport variability can be significant and should be considered in interpretations of observed CO_2 variability. The CCM2 runs recycle a single year of winds while the NCEP runs use wind fields that exhibit realistic transport inter-annual variability. CO_2 sources are taken from transient simulations (i.e., with inter-annual variability) of the terrestrial carbon fluxes by TEM (Terrestrial Ecosystem Model) and the LPJ (Lund-Potsdam-Jena) models forced with climate data from Jones (1994) and Hulme (1992 & 1994). The two ecosystem models bracket the range of simulated behavior, with the TEM fluxes exhibiting much less year to year variability than LPJ, in part due to TEM taking into account nitrogen limitations while LPJ includes fire disturbance. A sensitivity experiment with the NCEP dynamics was also conducted with a repeated seasonal cycle of CO_2 fluxes to isolate the impact of transport variability explicitly. We show that the difference between the CCM2 and NCEP runs is primarily due to transport variability and that the inclusion of the year to year changes in circulation significantly improves the correlations of the simulated and observed deseasonalized concentration anomalies in both the TEM and LPJ cases. The inclusion of transport inter-annual variability also increases the magnitude of the variability in the simulated concentrations anomalies, shifting the standard deviations from TEM and LPJ simulations closer to and in excess of the observed values, respectively. These experiments highlight the need to use realistic inter-annual forcing in model-data comparisons.

B51C-12 1150h

Simulation of Interannual Variability in the Terrestrial Carbon Cycle

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Recent observational and modeling studies have shown that the net flux of carbon from the global terrestrial ecosystem is subject to substantial interannual variability. We use an integrated atmospheric general circulation and biosphere dynamics model to investigate the nature and source of this variability in the terrestrial carbon cycle. The Community Climate Model 3 (CCM3) coupled to the Integrated Biosphere Simulator (IBIS 2) is used to perform a 16-member ensemble of AMIP-type present day simulations with observed sea surface temperatures (SSTs) for the period 1979-1992. Interannual global variations in terrestrial carbon uptake as simulated are of the proper magnitude and have good positive correlation with inferred uptake from observationally driven inverse modeling for the same time period. While our ensemble simulations do permit the extraction of a SST-driven signal, they also show that nearly 65% of interannual variability is driven by "internal" chaotic climate variability not related to variations in SST. This unforced interannual variability in carbon uptake appears to originate mainly from the unforced variability in Net Primary Productivity which in turn is driven by the chaotic variability in interannual precipitation and surface temperature.

B06. Water, Energy, and Carbon Cycles in Terrestrial Systems: Measuring and Modeling From Site to Region Sponsor: Biogeosciences

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B52A MC: 122 Friday 1330h

Synthetic Analyses of Large-Scale Ecological Processes II

***Presiding:* G Hurtt,** University of New Hampshire**; J Foley,** University of Wisconsin

B52A-01 1330h

The Synthesis Challenge

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Terrestrial ecosystems are heterogeneous across a wide range of spatial and temporal scales. This heterogeneity poses major challenges for observation, experimentation, modeling, and ultimately the synthetic understanding of important large-scale ecological processes. From leaf level measurements to plot scale experiments, from towers to forest inventories, from remote sensing to integrated atmospheric observations, approaches are needed for simultaneously interpreting such heterogeneous data in a self-consistent manner. In this talk, I will motivate and provide some perspectives on emerging synthetic approaches for large-scale ecosystem analysis.

B52A-02 1345h INVITED

Synthesizing the Global Biogeochemical Cycle of Boron

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B

To understand human impacts on earth system function, we must develop internally consistent models for the biogeochemical cycle of major elements. We will show approaches to this challenge using, as an example, our recent attempt to synthesize the global boron cycle, using the few data currently available. The global B cycle is primarily driven by a large flux (1.38 TgB/yr) through the atmosphere derived from seasalt aerosols. Other significant sources of atmospheric boron include emissions during the combustion of biomass (0.26-0.43 TgB/yr) and coal, which adds 0.19 TgB/yr as an anthropogenic contribution. These known inputs to the atmosphere cannot account for the boron removed from the atmosphere in rainfall (3.8 TgB/yr), estimated dry deposition (0.8 to 2.2 TgB/yr) and the gaseous absorption of B by the oceans (1.2 TgB/yr). In addition to atmospheric deposition, rock weathering is a source of boron (0.19 TgB/yr) for terrestrial ecosystems, and humans mine about 0.31 TgB/yr from the Earth's crust. More than 4.8 TgB/yr circulates in the biogeochemical cycle of land plants, and about 0.51 to 0.61 TgB/yr is carried from land to sea by rivers. The biogeochemical cycle of boron in the sea includes 4.4 TgB/yr circulating in the marine biosphere, and an annual loss of 0.47 TgB/yr to the oceanic crust via a variety of sedimentary processes that collectively remove only a small fraction of the total annual inputs to the oceans. Thus, with our current understanding of the global biogeochemistry of B, the atmospheric budget shows outputs>inputs, while the marine compartments show inputs>outputs. Despite these uncertainties, it is clear that the human perturbation of the global B cycle has more than doubled the mobilization of B from the crust and contributes significantly to the B transport in rivers.

B52A-03 1400h

Large-scale Ecological Processes: the View from the Air

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The processes of photosynthesis, respiration, and transpiration may be observed on the scale of a region or continent by measuring the changes in atmospheric CO2 and H2O from an aircraft platform. This paper reviews atmospheric measurements from a number of aircraft campaigns that allow diagnostic determination of large-scale fluxes of CO2 from tropical and midlatitude ecosystems. The signal of large-scale ecosystem processes is shown to provide clear, quantitative information on the largest scales of aggregation. We give several examples to show that the emergent properties of ecosystems are quantitatively and qualitatively different than small-scale properties. Mechanistic models of ecosystems on large scales must account for landscape-scale processes such as transport and deposition of organic matter, nutrients, and pollutants, as well as land use and fire history.

B52A-04 1415h INVITED

Carbon Cycle Model Linkage Project (CCMLP): Evaluating Biogeochemical Process Models with Atmospheric Measurements and Field Experiments

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Models of biophysical and biogeochemical proceses are being used -either offline or in coupled climate-carbon cycle (C4) models-to assess climate- and CO2-induced feedbacks on atmospheric CO2. Observations of atmospheric CO2 concentration, and supplementary tracers including O2 concentrations and isotopes, offer unique opportunities to evaluate the large-scale behaviour of models. Global patterns, temporal trends, and interannual variability of the atmospheric CO2 concentration and its seasonal cycle provide crucial benchmarks for simulations of regionally-integrated net ecosystem exchange; flux measurements by eddy correlation allow a far more demanding model test at the ecosystem scale than conventional indicators, such as measurements of annual net primary production; and large-scale manipulations, such as the Duke Forest Free Air Carbon Enrichment (FACE) experiment, give a standard to evaluate modelled phenomena such as ecosystem-level CO2 fertilization. Model runs including historical changes of CO2, climate and land use allow comparison with regional-scale monthly CO2 balances as inferred from atmospheric measurements. Such comparisons are providing grounds for some confidence in current models, while pointing to processes that may still be inadequately treated. Current plans focus on (1) continued benchmarking of land process models against flux measurements across ecosystems and experimental findings on the ecosystem-level effects of enhanced CO2, reactive N inputs and temperature; (2) improved representation of land use, forest management and crop metabolism in models; and (3) a strategy for the evaluation of C4 models in a historical observational context.

B52A-05 1430h INVITED

Sustainability of Terrestrial Carbon Sinks

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The problem of predicting the future trajectory of terrestrial carbon sinks has five components. These are (1) the attribution of current sinks among causal mechanisms, (2) the intrinsic trajectory of the sink resulting from each mechanism, (3) the future trajectory of environmental conditions, (4) the sensitivity of sinks to future environmental conditions, and (5) the prospect for future sinks due to novel mechanisms. This analysis of sinks must be placed in the broader context of carbon balance, including not only sinks, but also sources.

The attribution problem is central to the question of the future of carbon sinks because each of the potential mechanisms has different intrinsic dynamics, responds differently to environmental changes, and is influenced by a different set of human actions. Until recently, most analyses assumed that the past and future trajectory of terrestrial carbon sinks could be understood as a function of climate and atmospheric composition alone, without a major contribution of direct effects of human actions. Increasingly, it is clear that this perspective is too limited. In many settings, current sinks are probably dominated by the history of land management. Interactions among these major regulators may be as important as the single-factor effects.

As emphasis on CO_2 and climate as the sole or dominant explanation for terrestrial sinks has faded, a number of new potential mechanisms have emerged, including, (1) climate change, (2) CO_2 fertilization, (3) nitrogen fertilization, (4) the regrowth of previously harvested forests, (5) the abandonment of agricultural land, (6) changes in agricultural management, (7) increasing woodiness of grassland and savanna vegetation, (8) fire suppression, (9) accumulation in landfalls, and (10) accumulation in durable products. None of these mechanisms produces an indefinite sink. For some mechanisms, the potential is influenced primarily by the interaction between ecosystem processes and the trajectory of climate and atmospheric change. For others, the historical pattern of human actions is the dominant influence. These two classes of regulators interact for all of the mechanisms.

B52A-06 1445h INVITED

Measuring the Human Footprint on Ecosystem Function

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Major questions for the biogeosciences concern the consequences of human transformation of landscapes for biogeochemical cycling and other ecosystem functions. While it is clear that the footprint of humans extends to almost all corners of the world, there is no single measure of the anthropogenic effect on ecosystems. Unlike the "Keeling curve" representing anthropogenic carbon dioxide emissions in a single atmospheric measurement, the spatial and temporal heterogeneity of ecosystems and the patchy nature of human activities on the landscape make such a measurement impossible. Here we present two approaches for assessing the consequences of human modification of the landscape on ecosystem processes: the effects of past and future land use change on net primary production at the global scale and analysis of satellite observations over the past 18 years to quantify the carbon dioxide emissions from tropical land use change. Key issues for quantifying human influences on ecosystem function include accounting for natural variability on a variety of time scales and incorporating spatial heterogeneity in landscape-level analysis.

B52A-07 1500h

Human Activity and a Changing Biosphere – A Review

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As we take a more complete and synthetic view of the biosphere, we must also recognize the important human dimensions affecting the planets ecosystems. The use of ecosystems as sources of food, fiber, freshwater, and other ecosystem services has radically transformed the nature of the biosphere.

In this presentation, I will attempt to review some of the human activities affecting ecosystem processes on regional and global scales. In addition, examples of how human activities can be directly incorporated with ecological models will be illustrated.

B52B MC: 122 Friday 1530h

Synthetic Analyses of Large Scale Ecological Processes: The North American Carbon Sink as a Case Study

Presiding: **C Potter,** NASA-Ames Research Center**; J Coughlan,** NASA Ames Research Center

B52B-01 1530h

Observational Evidence of a Large CO2 Sink in North America?

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The concentration of atmospheric CO2 over the North Atlantic basin, downwind from the continent of North America, is on average somewhat lower than over the North Pacific basin. The reason could be unexpectedly large uptake of CO2 on the North American continent, larger "local" uptake of CO2 by the North Atlantic than by the North Pacific, or some combination of the two. Our analysis of these hypotheses is strongly data-oriented. Use is made of spatial gradients of other atmospheric species, namely the isotopic ratio 13C/12C of CO2, CO, SF6 in order to arrive at an estimate of a sink in North America. The 13C/12C ratio of CO2 is enriched over the North Atlantic relative to the Pacific, suggesting the presence of a biological sink upwind of the Atlantic. Sampling stations in both basins are not located at the same latitudes, so that the contamination of the (small) east-west differences by the (larger) north-south gradient has to be removed. Statistical uncertainty of the concentration differences is estimated by a Monte Carlo technique in which observation stations are added and removed.