SIMULATION OF BOREAL ECOSYSTEM CARBON AND WATER BUDGETS pdf

1: Projects and Data - Numerical Terradynamic Simulation Group - University Of Montana

Simulation of boreal ecosystem carbon and water budgets: scaling from local to regional extents, grant: NAG, final report Author: Eric F Wood ; United States.

The objective of this program is to quantify the exchange of energy, water, and greenhouse gases between boreal forests and the atmosphere. Important factors that influence the interaction between boreal forests and the atmosphere include forest type, which is strongly influenced by geomorphology, disturbance history, and climate change. To this end, separate studies have been designed to quantify how carbon, water and nutrients exchange between the boreal forest and the atmosphere following logging and wildfire - two important disturbances of boreal forests. A second objective is to quantify the effects of anticipated warming on carbon and water exchange between boreal forests and the atmosphere. Project Methods The three major objectives of this study are as follows. Model simulations will be compared to field data at a range of temporal and spatial scales. The second program will use replicated warmed open top chambers nested on soil warming plots and fertilized plots no warming in young boreal forests in northern Manitoba to examine the effects of ecosystem warming versus increased nutrient availability on the structure and function of a boreal black spruce forest. The overall objective of this project was to better understand the effects of disturbance and climate change on ecosystem dynamics of the boreal forest in central Canada. Because of the the research was conducted on First Nation land, we have also shared our results with members of the First Nation Natural Resource board. Lastly, the results have been presented at national and international conferences and published in peer-reviewed journals. All of the above named scientists were trained in ecosystem ecology. The primary collaborating agencies were Manitoba Hydro and Manitoba Conservation; the primary contacts for the two Canadian agencies were Brendan Carruthers and Bruce Holmes, respectively. Our effort concentrated on relaying our findings to these groups and discussing how the results might affect their decisions forest management, fire suppression, climate change mitigation. Nothing significant to report during this reporting period. Impacts Two key finds were 1 wildfires have significantly changed the carbon balance of the central Canadian boreal forest from a carbon sink to a carbon source, and 2 experimental warming of the soil and vegetation did not stimulate a large increase in heterotrophic respiration, as was feared. These two key findings have immediate and direct impacts on carbon management and mitigation of boreal forests. Fire suppression could be an important, but costly, C mitigation management activitiy. Also, anticipated climate warming does not appear to increase the release of carbon dioxide CO2 to the atmosphere. Research outputs include analyzing data that were collected at the very end of the project, decommissioning the research site in Thompson, Manitoba, Canada, preparing synthesis manuscripts,and presenting scientific findings at Ecological Society of America and American Geophysical Union meetings. In addition, I was invited to Portugal to assist a research team in ecosystem research in fire-prone terrestrial ecosystems. Not relevant to this project. The target audience for this project is both scientists, land managers, and policy makers for the reasons mentioned above in the Impact section. No major changes in approach were made. Impacts The scientific findings continue to have increased importance as Canada and the United States develop strategies to mitigate carbon emissions and enhance carbon sequestration by forest ecosystems. Our ongoing research with remotely sensing moss cover is critical because carbon uptake by mosses can exceed that of trees, but is also highly variable depending upon the species of moss! The completed modeling efforts of the effects of fire on water budgets of boreal forests is also relevant to policy makers because the central Canadian provinces are major producers of hydro power and that power is sold as far south as Texas. Effects of fire on regional evapotranspiration in the central Canadian boreal forest. Bryophyte cover estimation in a boreal black spruce forest using airborne lidar and multispectral sensors. The outputs of this project were disseminated via popular newspaper articles, and providing interviews for regional and national radio and TV stations. Gower provided numerous interviews to Canadian TV and radio companies located in British Columbia, Saskatchewan, Manitoba, Ontario, and Quebec, as well

as, a phone interview for the Nature podcast. Graduate students working on this project included Dustin Bronson and Shawn Serbin; the post-doc on the project was Ben Bond-Lamberty; the research intern on the project was Scott Peckham; the Associate scientist was Douglas Ahl. The project was supervised by Professor Stith T. Partner organizations included Manitoba Conservation and Manitoba Hydro. Training and professional development opportunities were provided to the graduate student and staff by allowing them to attend various national American geophysical Union annual meetings in San Francisco, CA and international meetings. The target audience that this project was designed to result in change in knowledge and action was forest land mangers and policy makers. The effects of climate change on the ability of boreal forests to continue to sequester carbon is of great interest because the potential impact the boreal forest could have on atmospheric CO2 concentration. Our efforts to examine the effects of climate change and wildfire on the boreal forest carbon budget clearly showed that wildfire has a much greater effect on carbon exchange between the boreal forest and the atmosphere, than climate warming. This change in knowledge will likely have profound effects on the actions of policy makers in Canada. Impacts The scientific findings that were developed from the project were used to produce project outcomes that will have a significant impact on how the Canadian boreal forests is viewed as a carbon sink or source. Specifically, our model results clearly showed that increased wildfire frequency changed the boreal forests in Saskatchewan and Manitoba from a weak carbon sink to a weak carbon source. This key finding was published in the scientific journal, Nature, which has the highest impact factor of any scientific journal. Decomposition and fragmentation of coarse woody debris: Plant C allocation effects on ecosystem C cycling in boreal black spruce forests. Global Change Biology in press. Effects of ecosystem warming on boreal black spruce bud burst and shoot growth. This key finding was published in the scintific journal, Nature, which has the highest impact factor of any scientific journal. Global Change Biology in revision. Bond-Lamberty B, Peckham, S. The dominance of fire in deter-mining carbon balance of the central Canadian boreal forest. Estimation of stand-level leaf area for boreal bryophytes. Improved simulation of poorly drained forest using Biome-BGC. Response of soil surface CO2 flux in a boreal forest to ecosystem warming. Serbin, and ST Gower. Fire-induced changes in start of the growing season and leaf maturity in Canadian forests measured by satellite remote sensing. Remote Sensing of the Environment accepted pending revision Serbin, S. Canopy dynamics and phenology of a boreal black spruce wildfire chronosequence. Agriculture and Forest Meteorology accepted pending revision. The wildfire projected demonstrated that increased wildfire frequency in the central Canadian provinces has decreased the carbon sink strength of the boreal forest, while climate warming and elevated CO2 during the past 50 years has increased the carbon sink strength a very small amount. Impacts The wildfire study clearly demonstrates that managing wildfires is a valid C management strategy. Results from the warming experiment indictae climate warming will not cause large releases of CO2 to the atmosophere from the soil. Spatial dynamics of soil moisture and temperature in a black spruce boreal chronosequence, Canadian Journal of Forest Research 36 Nitrogen dynamics of a boreal black spruce fire chronosequence, Biogeochemistry 81 1: Simulation of boreal black spruce chronosequences: Bond-Lamberty, Gower, and Ahl Bond-Lamberty and Gower Estimation of stand-level leaf area for boreal bryophytes, Oecologia x: Key findings from the warming study to date are: We are currently analyzing aboveground growth measurements. Impacts The results of the studies will assist land managers and policy makers in determining cost-effective management practices that produce wood fiber, maintain biodiversity, and reduce greenhouse gas emissions. Results from the wildfire study are relevant to wildfire management strategies. The preliminary findings from the boreal forest warming study also provide valuable insight into earth system science modellers that soil surface CO2 flux will not likely increase in response to warming like early models had predicted. Nitrogen dynamics of a boreal wildfire chronosequence. Spatiotemporal measurement and modeling of boreal forest soil temperatures. Effects of stand age and tree species composition on transpiration and canopy conductance of boreal forest stands. We observed earlier bud-break and shoot growth in the warmed versus control plots and increased diameter growth. The warmed plots did not have significantly greater soil surface CO2 flux rates, suggesting that

climate warming will make boreal forests a stronger carbon sink - not a carbon source - as has been suggested by other scientists. Funding for the project was extended for an additional three years and we will continue the treatments. Impacts Wildfire, logging and climate warming are three major global changes that are affecting boreal forests. Our wildfire chronosequence study clearly shows that the boreal forest is a net C sink, even when the effects of wildfire are included. The preliminary data from the boreal forest whole ecosystem warming experiment suggest that climate warming will stimulate tree growth and make the boreal forests an even stronger carbon sink. These data will help earth system modelers constrain their models and illustrate the effects of wildfire on CO2 concentrations in the atmosphere. A reimplementation of the Biome-BGC model supporting multiple interacting vegetation types. Tree Physiology in press. The contribution of root respiration to soil surface CO2 flux in boreal black spruce chronosequence. A global relationship between heterotrophic and autotrophic components of soil respiration. Global Change Biology Net primary production of a bo-real black spruce wildfire chronosequence. The final phase of the project is to use the results of the field measurements to parameterize an ecosystem model and test hypotheses about the effects of wildfire frequency and intensity on net CO2 exchange between boreal forests and the atmosphere. Key findings of the field measurements are: Impacts Our results are the first to-date to estimate net exchange of carbon between boreal forests, the second largest forest biome in the world, and the atmosphere. Our data clearly show that the boreal forest is a net C sink, even when the effects of wildfire are included. Patterns and mechanisms of the forest carbon cycle. Annual Reviews Energy and Environment Carbon distribution and accumulation in a boreal black spruce fire chronosequence. Global Change Biology 9: Soil surface CO2 flux in a boreal black spruce fire chronosequence. Journal of Geophysical Research D3: The use of multiple measurement techniques to refine estimates of conifer needle geometry. Canadian Journal of Forest Research

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2: ORNL DAAC BIOME-BGC: TERRESTRIAL ECOSYSTEM PROCESS MODEL, VERSION

A coupled water and energy balance model is developed. This model can predict the partitioning of water and energy between major source, sink and storage elements within the Boreal-Ecosystem.

The MODIS data products are a core component of Earth science research and global environmental monitoring capabilities. NTSG developed a global land parameter data record LPDR from calibrated AMSR observations, including daily surface air temperature, soil moisture, vegetation optical depth, atmosphere precipitable water vapor, surface water inundation dynamics and land surface freeze-thaw status. The LPDR is publicly available and supports a wide range of hydrological and ecological studies. The Landsat NDVI Normalized Difference Vegetation Index is sensitive to variations in vegetation greenness and is widely used in ecology, forestry, agriculture, wildlife and other applications. In contrast with previous upscaling methods, the DRT algorithm utilizes information on global and local drainage patterns from baseline fine scale hydrography to determine upscaled flow directions and other critical variables including upscaled basin area, basin shape and river lengths. We applied a satellite remote sensing based evapotranspiration ET algorithm to assess global terrestrial ET. The algorithm quantifies canopy transpiration and soil evaporation using a modified Penman-Monteith approach with biome-specific canopy conductance determined from the NDVI, and quantifies open water evaporation using a Priestley-Taylor approach. The resulting geospatial lake ice record provides relatively precise mapping of daily ice cover variations for more than lakes 76, lake pixels. In this study we developed a satellite data driven approach for mapping and monitoring recent changes in permafrost active layer depth across Alaska. The FT-ESDR classifies the daily frozen or non-frozen status of the landscape for all global land areas where frozen temperatures are a significant constraint to surface water mobility and ecosystem processes. RAP provides quantitative spatial metrics on habitat extent and quality for more than river systems, and has been used identify and evaluate critical habitat areas and their vulnerability for the major salmonid species. Biome-BGC is a computer program that estimates fluxes and storage of energy, water, carbon, and nitrogen for the vegetation and soil components of terrestrial ecosystems. North American Carbon Program NACP - Approximately percent of the North American region 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 surface and soil freeze-thaw state is closely linked to vegetation phenology and growing season dynamics in northern temperate, sub-alpine, boreal and arctic biomes. These impacts are related to growing season length for evergreen ecosystems, to timing of leaf flush and senescence for drought- or cold-deciduous systems, and to seasonal and annual variability in canopy biomass. Spaceborne remote sensing is the only practical tool for monitoring seasonal vegetation dynamics globally with high temporal repeat and moderate spatial resolution. Terrestrial Carbon Flux - We are developing a new satellite-based approach for regional assessment and monitoring of terrestrial net carbon exchange NEE for the pan-Arctic; NEE quantifies the magnitude and direction of land-atmosphere net CO2 exchange and is a fundamental measure of the balance between carbon uptake by vegetation net primary production NPP and carbon loss through soil heterotrophic respiration Rh. Daymet - is a group of computer programs that produce surfaces of daily temperature, precipitation, radiation, and humidity over large regions, taking into account the effects of complex terrain. MT-CLIM - is a computer program that uses observations of daily maximum temperature, minimum temperature, and precipitation from one location the "base" to estimate the temperature, precipitation, radiation, and humidity at another location the "site". TopoWx - "Topography Weather" is an meter resolution gridded dataset of daily minimum and maximum air temperature for the conterminous U. The objective of TopoWx is to provide gridded temperature estimates that accurately capture both 1 locally relevant topoclimate spatial patterns; and 2 regional climate variability and trends. SGI has matured into acatalyst for rangeland and wildlife conservation across the North American west, focusing on the sharedvision of conservation through sustainable working landscapes and

providing win-win solutions forproducers; sage-grouse and other wildlife species; and rangelands as a whole. SGI science partnersdevelop and utilize geospatial products to target, assess, and monitor conservation outcomes. Most regional observation networks indicate that dramatic changes have occurred across the Arctic in recent decades, but comparatively little work has been done to assess atmospheric and oceanic responses to the dramatic observed terrestrial changes. Both increases in surface air temperature and a shift in arctic air circulation patterns are likely to contribute to changes in ice distribution. The scope of this multidisciplinary project is develop online, near-real time capabilities for rapid assessment and monitoring pan- Arctic water budgets and river discharge to the Arctic Ocean. As such, many studies have successfully used AVHRR normalized difference vegetation index NDVI to infer photosynthetic monitor growing season phenology and estimate vegetation. The Lake is oligotrophic, yet experienced an increase in eutrophication from to , and two lakewide blooms of macroalgae in and that represented anomalous declines in water quality likely due to increasing nutrient inputs from anthropogenic sources. We are working with colleagues at the NASA Jet Propulsion Laboratory to develop new satellite microwave remote sensing algorithms for detecting and monitoring land-atmosphere water and energy exchange over North America. While urban areas have generally a lower photosyntheticcapacity than the surrounding rural environments, intensively irrigated and fertilized lawns and trees often counterbalance the decline in net primary productivity NPP due to the replacement of vegetated surface with constructed materials. The NTSG portion of this investigation focused on assessing annual variability and regional trends in vegetation productivity for the WALE domain of Alaska and NW Canada, and the primary mechanisms driving observed changes over the year - study period. However, while retrospective analyses provide insight into past performance, they do little to satisfy the need for near real time yield information.

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3: Carbon Cycling in the Boreal Forest - UNIV OF WISCONSIN

A coupled water and energy balance model is developed. This model can predict the partitioning of water and energy between major source, sink and storage elements within the Boreal-Ecosystem-Atmospheric Study (BOREAS) areas.

Biome-BGC is a computer program that estimates fluxes and storage of energy, water, carbon, and nitrogen for the vegetation and soil components of terrestrial ecosystems. The primary model purpose is to study global and regional interactions between climate, disturbance, and biogeochemical cycles. Biome-BGC represents physical and biological processes that control fluxes of energy and mass. These processes include the following: New leaf growth and old leaf litterfall Sunlight interception by leaves and penetration to the ground Precipitation routing to leaves and soil Snow accumulation and melting Drainage and runoff of soil water Evaporation of water from soil and wet leaves Transpiration of soil water through leaf stomata Photosynthetic fixation of carbon from CO2 in the air Uptake of nitrogen from the soil Distribution of carbon and nitrogen to growing plant parts Decomposition of fresh plant litter and old soil organic matter Plant mortality Fire The model uses a daily time-step, meaning that each flux is estimated for a one-day period. Between days the program updates its memory of the mass stored in different components of the vegetation, litter, and soil. Weather is the most important control on vegetation processes. Flux estimates in Biome-BGC depend strongly on daily weather conditions. Model behavior over time depends on climate--the history of these weather conditions. Additional information can be found on there web site at: Cite this model product as follows: Terrestrial Ecosystem Process Model, Version 4. Journal of Geophysical Research D Canadian Journal of Forest Research Agriculture and Forest Meteorology Ecohydrological changes in the Murray-Darling Basin. A simulation of regional hydrological changes. Journal of Applied Ecology, Ecological Applications, 4 2: A general model of forest ecosystem processes for regional applications I. Hydrological balance, canopy gas exchange and primary production processes. Dynamic carbon allocation and nitrogen budgets. Field Editors , Scaling Physiological Processes: Modeling and measuring the effects of disturbance history and climate on carbon and water budgets in evergreen needleleaf forests. Agricultural and Forest Meteorology, , Journal of Vegetation Science 5: Earth Interactions 4, Paper No. Element interactions in forest ecosystems: There is also a companion file of model release documentation, http:

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