

Warming experiment, spectral observation and model analysis for predicting global warming effects on forest carbon cycle

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Estimation of global warming effects on photosynthesis and respiration in forest ecosystems based on mechanistic understanding is one of the most crucial research under the current climate change condition. The knowledge and insights gained by such research would be necessary for our further evaluation of ecological, biogeochemical and societal functions of our ecosystems ranging from local, national land to Asian scales. In Takayama site, Gifu University (Japan), efforts have been made for nearly 20 years to clarify the micrometeorological and ecological understandings on the carbon cycle in a deciduous broadleaf forest located on a mountainous landscape in central Japan. Recently we established a multidisciplinary research named "Satellite Ecology" to link ecophysiology, micrometeorology and remote sensing to encourage cross-scale observation and mechanistic understanding on the forest ecosystems. In this paper we introduce our new project named "Satellite Ecology II", in which in-situ artificial warming experiments for forest canopy tree and soil are established. Here we examine the warming effects on foliage photosynthesis and soil respiration, explore the remote sensing techniques to detect any ecophysiological changes in the canopy, and predict the near-future changes in forest carbon cycle.

Increasing air temperature (+5 degreeC) surrounding a branch of canopy tree, *Quercus crispula*, by installing an 'Open-Top Canopy Chamber (OTCC)' resulted in earlier leaf expansion (5 days) and delayed leaf senescence (5 days) than the non-warming branch, and about 10% higher photosynthetic rate in summer. Increasing soil temperature (+3 degreeC) by installing heating cables at 3-5cm below the soil surface resulted in stimulation of soil respiration from spring to late growing season. Preliminary prediction of warming effects on leaf phenology, photosynthesis and respiration of the forest revealed that increasing temperature may enhance the growing season of the deciduous trees and hence both photosynthesis and respiration of entire forest.

Keywords: forest ecosystems, photosynthesis, global warming, carbon cycle

Long-term monitoring of ecosystem by Phenological Eyes Network

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Satellite remote sensing (RS) is a strong methodology in the study of terrestrial ecosystems. For example, RS is used in scaling up of the ground measurements of carbon flux, water flux, biomass, etc. from a site scale to a regional or global scale. RS provides numerical regional ecological models with information for initial conditions, boundary conditions, and validation. For the sake of it, various new satellite sensors have been designed and launched. They are now delivering a lot of high-level products regarding to the terrestrial ecology, such as new vegetation indices, LAI, FPAR, phenology, GPP, and NPP.

However, in the ecological standpoint, these RS methodology has not enough checked or validated on the ground level. Because an essential characteristics of ecosystem is its dynamism (especially the seasonal change, or "phenology"), the accuracy, quality, and interpretation of the RS data should be also studied dynamically. For the sake of it, a stable, continuous, long-term, and multi-ecosystem ground validation network is desired. Of course, the flux observation networks such as AsiaFlux have potential to contribute to it. However, because RS observes vegetation's optical characteristics rather than carbon or heat flux, we need to include optical (spectral) observation in the validation of ecological RS. We believe that the ecological interpretation of RS data is possible only if it is based on a careful theoretical and experimental study of the relationships between optical characteristics and ecological structure (or function), using the quality-controlled RS data considering the relevant noise factors such as cloud contamination or atmospheric aerosols.

With this background stated above, we started the "Phenological Eyes Network (PEN) in 2003. PEN is a network of ground observatories for long-term automatic observation of the vegetation dynamics (phenology), vegetation's optical properties (such as spectral reflectance), and the atmospheric optical properties (such as aerosol optical thickness). Most PEN ground sites have been set up at the AsiaFlux sites. The collaboration of PEN and AsiaFlux is critically important in the interpretation of the optical signals captured by RS in terms of ecology (especially the terrestrial carbon/water cycles).

Keywords: phenology, remote sensing

A model-data integration framework to a terrestrial ecosystem model using multiple satellite-based constraints.

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Various satellite-based spatial products, such as evapotranspiration (ET) and gross primary productivity (GPP), are now available by integration of ground observation and satellite observation. Therefore, effective use of these multiple spatial products to terrestrial biosphere models is an important step toward better simulation of terrestrial carbon and water cycles. However, due to the complexity of terrestrial biosphere models with a large number of model parameters, the application of these spatial data sets to terrestrial biosphere models is difficult.

In this study, we show an effective but simple framework to refine a terrestrial biosphere model, Biome-BGC, using multiple satellite-based products as constraints, and tested it in the monsoon Asia region (60E-180E and 80N-10S) covered by eddy-covariance observations. The framework is based on the hierarchical analysis (Wang et al. 2009) with model parameter optimization constrained by satellite-based spatial data. The Biome-BGC model is separated into several tiers to minimize the freedom of model parameter selections and maximize the independency from the whole model. For example, the snow sub-model is first optimized using satellite-based snow cover product, followed by soil water sub-model optimized by satellite-based ET (estimated by an empirical upscaling method), photosynthesis model optimized by satellite-based GPP, and respiration and residual carbon cycle models optimized by biomass data.

As a result of initial assessment, we found that the most of default sub-models (e.g. snow, water cycle and carbon cycle) showed large deviations from satellite-based products; however, these biases were removed by applying the method. For example, gross primary productivities were overall underestimated in boreal and temperate forest and overestimated in tropical forests. However, the parameter optimization scheme successfully reduced these biases. Our analysis shows that terrestrial carbon and water cycle simulations in monsoon Asia were greatly improved, and the use of multiple satellite observations with this framework is an effective way for improving terrestrial biosphere models. We also found that respiration fluxes, biomass, and soil carbon data, which are currently unavailable, are also important to constrain simulated terrestrial carbon cycles and generation of these products are urgent.

Keywords: terrestrial biosphere model, remote sensing, optimization, carbon cycle, water cycle

How much complexity of plant canopy structure is good enough for the light environment simulation?

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Most land surface models assume that a plant canopy can be abstracted as a turbid medium to compute mass, energy, and carbon exchange. The canopy is horizontally homogeneous as leaves are randomly distributed in space. Consequently, radiation only changes in a vertical direction. Lambert-Beer type light penetration scheme is widely adapted for transmission and absorption simulation of a plant canopy. In this scheme, the incoming light exponentially decreases with an increase in leaf area. Leaf inclination angle and light incident angle is considered in the model. This model is only valid when the leaves are randomly distributed in space. To consider the spatial anisotropy of leaf distribution, Nilson (1971) introduced clumping modeling. By putting the clumping index into the Lambert-Beer equation, this scheme extends the light environmental computation for non-random distribution of leaves within a plant canopy. The clumping modeling is simple. Yet, there are some issues. For example, the clumping index is not a constant value. The clumping index changes with the light incidence angle and vertical levels. Also, we cannot directly measure the clumping index. The 3-dimensional modeling of forest light environment needs a lot of ecosystem structural data sets along with a vast computation time. The recent progress of measurement techniques (e.g. LiDAR) enables to run and evaluate the realistic light environment. In this presentation, I show some of the comparison results to see how the different complexities of light penetration modeling affect the light environment.

Keywords: radiative transfer, Land surface model, light environment

Global model inter-comparison with GOSAT L4A and support vector machine based estimates of biospheric variables

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Estimation of carbon exchange in terrestrial ecosystem associates with difficulties due to complex entanglement of physical, chemical, and biological processes: thus, the net ecosystem productivity (NEP) estimated from simulation often differs among process-based terrestrial ecosystem models. In addition to complexity of the system, validation can only be conducted in a point scale since reliable observation is only available from ground observations. With a lack of reliable spatial data, extension of model simulation to the global scale results in significant uncertainty in the future carbon balance and climate change. Greenhouse gases Observing SATellite (GOSAT), launched by the Japanese space agency (JAXA) in January, 2009, is the 1st operational satellite promised to deliver the net land-atmosphere carbon budget to the terrestrial biosphere research community. Using this information, the model reproducibility of carbon budget is expected to improve: hence, gives a better estimation of the future climate change.

Because of the direct association with climate change, improving estimation of global NEP is essential; yet, global gross primary productivity (GPP) and ecosystem respiration (RE) need to improve as well for further sophistication of ecosystem modeling. In the system of carbon cycle, GPP and RE are the true physiological quantities representing photosynthesis and respiration, and NEP is a byproduct of them. Since a major purpose of process-based ecosystem models is to clarify the mechanism of carbon cycle, it is important to invest efforts to refine GPP and RE as well.

Currently, the most reliable estimate of global GPP is provided by observation-based empirical upscaling with machine learning models [Jung et al. 2011]. Machine learning regression is based on a network of eddy covariance flux tower observation, in conjunction with global satellite remote sensing and meteorological data sets. Because of the high correlation with GPP, availability of long-term global observations of vegetation indexes (e.i. EVI, NDVI, and NDWI) from operational satellites makes performance of machine learning model finer in prediction of GPP. Because of limited availability of carbon pool data, however, it is difficult to induce equivalent performance in RE with machine learning models [Jung et al. 2011]. Instead of a direct estimation, combination of global GPP estimated by machine learning regression and NEP from GOSAT L4A would produce a more reliable budget of global RE.

This initial analysis is to compare a set of observation-based global carbon flux products, NEP from GOSAT L4A, GPP from support vector machine regression, and RE from a combination of them, with three types of TEMs and an inversion model: Biome-BGC (prognostic model), CASA (diagnostic model), LPJ (dynamic vegetation model), and Carbon Tracker (inversion model). Comparison was conducted with the standardized format based on GOSAT L4A: 42 sub-continental tiles and monthly temporal coverage from June 2009 to May 2010. Through the comparison, we discuss similarities and dissimilarities in (1) seasonal variations, (2) global and annual averages, (3) variability with climate (air temperature, precipitation, and solar radiation).

Reference

Jung, M., et al. (2011), Global patterns of land-atmosphere fluxes of carbon dioxide, latent heat, and sensible heat derived from eddy covariance, satellite, and meteorological observations, *Journal of Geophysical Research*, 116.

Acknowledgement

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Keywords: GOSAT, machine learning regression, terrestrial ecosystem model, carbon cycle

ADMIP: Asian Drylands Model Intercomparison Project

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In this presentation we introduce our ongoing project entitled Asian Drylands Model Intercomparison Project (ADMIP). As the name shows, the project focuses on the Asian drylands which comprise large portion of the Asian land surface. Due to small amount of rainfall and low productivity, the dryland ecosystem is vulnerable, and has large inter-annual variability. Such environment is difficult to simulate, and the model outputs have large variation.

The goals of the project are to assess the uncertainty in the model prediction, and to improve accuracy of the model prediction for the land surface environment. As the participants, we have 18 models including land surface models and terrestrial ecosystem models. Since these models have different focuses and different input/output variables, we needed study sites which cover a wide range of observation data, and as a result of discussion we selected Kherlenbayan-Ulaan in Mongolia and Tongyu in China. In addition to the ground-based observation data for model validation, in the experiments we also use remote sensing data as a complement to the station data and reanalysis data for spin-up.

The experiments have three stages: an experiment using the default parameter values (Stage 0), an experiment using the parameter values in the existing literature (Stage 1), and an experiment using the parameter values tuned to well-reproduce the observation in the important variables (Stage 2). In the presentation, we will show some results from Stages 0 and 1.

Keywords: Asia, Drylands, Terrestrial ecosystem models, Land surface models, Observation data

The assessments of climate change impact on global SOC stock by a model intercomparison project

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Although soils form a thin covering terrestrial earth's surface like a skin, soil organic carbon (SOC) is considered to be the largest carbon pool in terrestrial ecosystems. Global SOC stock reach 2 or 3 times higher than the amount of atmospheric CO₂. Therefore, in climate systems, because of the vast carbon pool of SOC, the behavior of SOC is the key to understanding the feedback of terrestrial ecosystems to atmospheric CO₂ concentration in a warmer world. SOC dynamics are critically affected by temperature and precipitation. In this study, we examined the SOC dynamics in 7 biome models obtained from the inter-sectoral impact model intercomparison project, which were simulated using 5 global climate models (GCMs) in the newly developed climate scenarios, i.e., representative concentration pathways (RCPs), aiming at specifying the uncertainty in the projection of global SOC stocks from global and regional perspectives. By the assumption that SOC is a one-compartment of earth system, we assessed global SOC turnover rate and the sensitivities to global mean temperature and precipitation anomalies by steady-state model.

In a higher forcing scenario (HadGEM forced with RCP8.5), inconsistent estimates of impact on the total SOC (2099–2100) were obtained from the different model simulations, ranging from a net sink by 347 Pg C to a net source by 122 Pg C. Cluster tree of the wavelet spectra for the SOC time-series data in all combination of simulations suggested that the uncertainties derived from the biome models overwhelmed those derived from the climate scenarios. Our simplified dynamic model (state-space model) for global SOC stock revealed that primarily balance by the global SOC stock turnover and Input from VegC are quite different among the biome models and further implies the different sensitivities to global mean temperature anomaly of the global SOC stocks among the biome models. On the other hand, global precipitation anomaly did not influence global SOC stock dynamics. Furthermore, the regional differences among ecosystem models will be discussed in this presentation.

Keywords: Soil organic carbon, RCP, GCM, Model intercomparison, Uncertainty

Calibrating the parameters of a crop growth model using MCMC algorithm with statistical yield data in global scale.

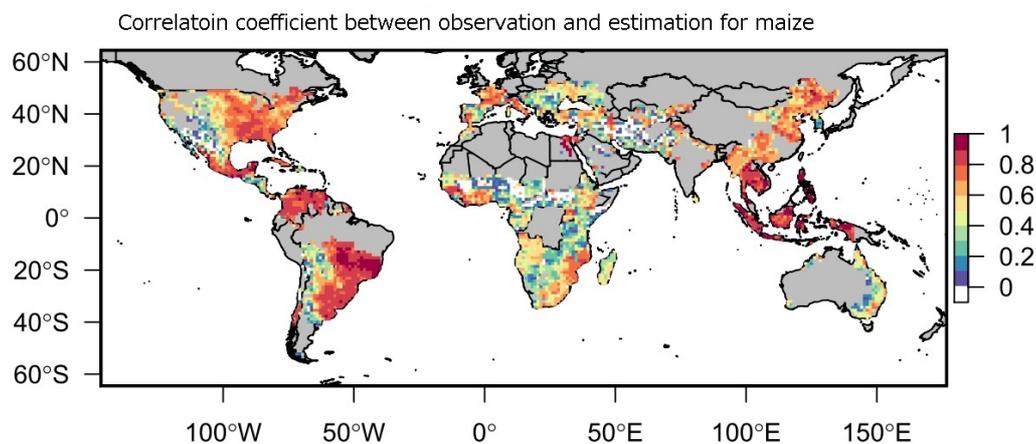
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In the land ecosystem, farmland area accounts for large proportion in land area, and plays an important role in the interaction between land ecosystem and atmosphere. In addition, in accordance with the rapid world population growth to be expected in the future, the rapid expansion of agricultural area would be also predicted. Therefore, to reveal the response of crop growth to climate change has become a critical issue. On the other hand, one of the major problems in evaluating crop production in global scale using process based crop model would be large spatial variations in crop varieties and farming method among regions. This non-uniformity should result in large variation in the responses of crop growth to the changes of temperature, precipitation, and atmospheric CO₂ concentration among regions. Therefore, it is important how we determine the model parameters for every region in global scale.

In this study, we have developed a crop growth model (PRYSBI2; Sakurai et al. in prep) to solve these problems, in which the parameter set were statistically calibrated using MCMC method for each region. The crop growth model has a large advantage in calibration of parameters in global scale because there is large number of data base about yield statistics in many countries. Recently, the data base about historical yield data was developed in which yield data was collected from bureaus of statistics of major crop-producing countries in state, county, or prefecture scale, and historical crop yields for each grid point of 1.125 deg x 1.125 deg (latitude by longitude) were estimated by averaging the yield data of the counties, states, or prefectures included in the grid (Iizumi et al. in prep). Using this global historical yield data, we estimated the posterior distribution of the parameter set of the model (PRYSBI2) for each grid point using Markov chain Monte Carlo methods (MCMC). The target crops were four major crops: maize, soybean, wheat, and rice. The selected target parameters were those relevant to crop varieties and regional variabilities, such as water stress, nitrogen stress, temperature dependency, and maturity. As the result, we obtained the model parameter set with large estimation capacity in global scale in which high correlation coefficient between historical yield data and estimated yield data for almost all grid points. In this presentation, we will discuss the past effect of climate change on past crop yields in global scale using this spatially tailored crop growth model.

Keywords: Agro-ecosystem, MCMC, crop yield, crop growth model, statistical yield data, global scale



Development of a global integrated model for predicting both crop production and water resources

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Crop growth mainly depends on a climate condition such as temperature, precipitation and solar radiation. Therefore, to assess climate change impacts on crop production, many studies have utilized a large-scale crop model which empirically and/or mechanistically can describe phenological development and crop production under a climate condition and an agricultural management. On the other hand, crop growth and production are largely affected by regional available water resources through an irrigation process. Future climate changes and increasing demand due to population increases and economic developments would intensively affect the availability of water resources for agricultural production. However, there are few large-scale crop models that can dynamically account for changes in crop production and water resources.

Therefore, we developed an integrated model for predicting both crop production and water resources. We coupled a large-scale crop model, PRYSBI2 (Sakurai *et al.* in prep), with a global water resources model, H08 (Hanasaki *et al.* 2008). The newly designed integrated model was consisting of five sub-models for the following processes: land surface, crop growth, river routing, reservoir operation, and anthropogenic water withdrawal. The land surface sub-model was based on a watershed hydrology model, SWAT (Neitsch *et al.* 2009). Surface runoff and percolation to aquifer simulated by the land surface sub-model were input to the river routing sub-model of the H08 model. A part of regional water resources available for agriculture, simulated by the H08 model, was input as irrigation water to the land surface sub-model. All processes in the integrated model were calculated on the daily time-step. The integrated model was applied to Northeast China, which has extensive crop land in China including present semi-arid climatic areas, and the region will be strongly affected by future climate change. This study verified the reproducibility of modeled elements in water balance over Songhua river watershed, which is main river watershed in Northeast China.

As the result, it was confirmed that biases between observations and estimations of soil water content and evapotranspiration were comparatively small, thus the integrated model can relatively reproduce the water balance over the watershed. Additionally, the large-scale crop model with estimated parameters at regional scale can faithfully reproduce the long-term trend and annual fluctuations in yield, especially in Northeast China Plain.

It is essential to estimate the regional water resources available in the contiguous watershed for evaluating actual crop productivity especially in drier region. Therefore, integrated model of crop productivity and water resources circulation in watershed is powerful tool for projecting climate change impacts on crop production.

Keywords: crop production, water resources, integrated model, large-scale

Terrestrial carbon cycle feedbacks in the Earth system models

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Anthropogenically emitted CO₂, which is partly absorbed by land and ocean ecosystems, produces energy imbalance on the Earth due to its greenhouse effect and leads to global climate change. Changes in atmospheric environment such as global warming and CO₂ increase can alter the various processes in the land ecosystems (e.g. photosynthesis, evapo-transpiration, ecosystem respiration, plant growth, and mortality). So far, two processes have been considered to be the major processes of the impact from environmental changes on terrestrial carbon cycle. The first is the climate impact on land ecosystems that is often called "climate-carbon feedback". One of the examples of this process is the enhanced ecosystem respiration due to warming, which can accelerate CO₂ increase in the atmosphere. The second is the impact of CO₂ increase on the land ecosystems. As CO₂ has a "fertilization effect" on plants because elevated CO₂ stimulates photosynthesis, plant growth can be promoted and resultant carbon accumulation occurs. This process is sometimes called "concentration-carbon feedback" and works as a negative feedback against CO₂ increase in the atmosphere. The balance of these two processes determines the magnitude of net carbon uptake in terrestrial ecosystems and thus could affect the degree of global warming. In this study, the strength of the carbon cycle feedbacks were evaluated by the Earth system models, which are advanced from climate models by incorporating biogeochemical processes and have been commonly used for long-term climate projections. First, we applied several scenarios to an ESM and found that the response of carbon cycle feedback evaluated by cumulative airborne fraction showed large variation among scenarios, likely due to the different response of concentration-carbon feedback across scenarios. Second, we applied a common scenario to multi-ESMs (this analysis was conducted as a joint research) and found that the strength of concentration-carbon feedback in terrestrial ecosystems showed the largest inter-model variation, largely affecting global carbon budget. This inter-model variation produces uncertain estimates of compatible fossil fuel emission that is the amount of emitted carbon to achieve a given atmospheric CO₂ pathway and calculated from the carbon budget estimated by ESMs. From these results, it was suggested that the strength of concentration-carbon feedback in terrestrial ecosystem is a key to reduce the uncertainty of projected climate by ESMs.

Effect of land-use and climate changes on carbon budget in Borneo Island using VISIT model

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More reliable estimation of carbon budget in forest ecosystems including the impact of deforestation is an important goal for environmental researchers. Carbon emission from land-use change accounts for about 20% of the total anthropogenic emissions worldwide. Especially, evaluation of carbon emission due to land-use change in tropical region is a very important task for management activities related to the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative. In previous regional-scale studies, many models have been applied to the deforestation impacts specifically in Amazonian forests, whereas only a few studies have investigated the impacts of land-use change occurring in Southeast Asia. In the present study, we estimated the carbon budget of Borneo Island in Southeast Asia using remote sensing data and a process-based terrestrial ecosystem model (VISIT), aiming at evaluating the differences of carbon budget between land-use and climate change.

To develop a broad-scale system of forest carbon monitoring, we used time-series data of forest coverage derived from satellite remote-sensing images to track a transition through forest disturbance history. We found that the active radar sensor PALSAR (Phased-Array L-Band Synthetic Aperture Radar) onboard the ALOS satellite is especially advantageous for monitoring tropical forest cover under clouds, and that temporal changes in forest coverage could be also detected using MODIS (MODerate resolution Imaging Spectroradiometer) data during the period from 2002 to 2008. Then, by applying the VISIT model to every grid point, we estimated the atmosphere-ecosystem exchange and internal dynamics of carbon at 1km resolution.

When the effect of land-use change was neglected, gross primary production (GPP), aboveground biomass, and soil respiration rate were overestimated by about 10 to 20% for the whole of Borneo Island. The difference of GPP between 1986 (a warm and wet year) and 1999 (a cool and dry year) was $3.01 \text{ tC ha}^{-1} \text{ yr}^{-1}$. On the other hand, when the land-use impact was included, GPP was estimated smaller by 3.33 to 5.15 tC ha^{-1} compared with estimates of the no-deforestation case. These results suggested that the effect of land-use change on carbon budget in the study area would be larger than that of climate variability, and that land management is very important for mitigation of global warming by reducing carbon emission. Additionally, we mention our preliminary estimation of the carbon budget under the future climate scenarios in Borneo Island.

Simulation study of the vegetation structure and function in eastern Siberian larch forests under changing climate

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Siberian larch forest covers is the largest coniferous forest region in the world; in this vast region, larch often form pure of nearly stands, regenerated by recurrent fire. This region is characterized by a short and dry growing season. With its huge area and vast potential carbon pool within the biomass and soil, Siberian larch forest likely plays a major role in the global carbon balance.

In this study, we refine the parameterization of the Spatially Explicit Individual-Based DGVM (SEIB-DGVM) (Sato et al., 2007, 2010) to the larch forest at Eastern Siberia. Unlike models those are employed by previous studies, SEIB-DGVM is based on individual trees, and thus it can analyze interactions between forest size structure (tree density and mean tree size) and ecosystem material cycles. With this model, we examined the impact of changes in climatic factors and parameters of plant-population dynamics on structures and ecological functions at Eastern Siberia.

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Sato, H., Kobayashi, H., & Delbart, N. (2010) Simulation study of the vegetation structure and function in eastern Siberian larch forests using the individual-based vegetation model SEIB-DGVM, *For. Ecol. Manage.*, 259, 301-311.

Keywords: Larch, Eastern Siberia, Permafrost, SEIB-DGVM, Wild fire, Simulation study

Interannual variation in ecosystem CO₂ exchanges in a semiarid grassland of Mongolia

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In Mongolia, grassland covers approximately 80% of the country and comprises a major part of East Asian grasslands. The plants live in a semiarid climate, and have often suffered from droughts. Exchange of CO₂ between grassland ecosystems and the atmosphere is controlled by environmental parameters such as temperature, soil moisture, and plant biomass. Studies have indicated that the grasslands respond sensitively to changes in climate, suggesting that interannual climate variability can lead to major changes in the CO₂ exchanges between the atmosphere and ecosystem. The objectives of this study are to estimate interannual variability of ecosystem CO₂ exchanges and to examine its controlling factors.

Our study site was located in a grassland area (47°02.6'N, 105°57.1'E) in Bayan-Unjuul (BU) county in central Mongolia, which contain typical steppe vegetation that is grazed by livestock. Rates of gross primary production (GPP) and ecosystem respiration (Reco) were measured using a closed-chamber technique during the growing seasons of 2004, 2005, 2006, 2009, 2010, and 2011. Net ecosystem CO₂ exchange (NEE) has also determined by an eddy covariance (EC) method since 2008. We set up automated weather and ground observation systems at site BU in June 2004, and standard meteorological and soil parameters were continuously measured at 30-minute intervals. Live aboveground biomass (AGB) was measured by clipping green parts of the vegetation and oven-drying them at 80°C for 48 hours for each point where the closed-chamber measurements were made. Based on the results of our measurements, we constructed an empirical model in which the rates of GPP and Reco are computed from the air and soil temperatures, vapor pressure deficit, photosynthetically active radiation, soil water content, and AGB. In this study, the half-hourly rates of GPP and Reco during the growing season (May-September) from 2007 to 2011 at site BU were calculated from the observed meteorological and soil parameters. Since AGB was not continuously measured at site BU, temporal changes in AGB were estimated from a remotely sensed vegetation index (NDVI). The model was validated by comparing the observed NEE by EC technique and the calculated values. The comparison demonstrated that our model was able to reproduce the carbon budget in the semiarid grassland with high accuracy. Cumulative rates of NEE during the growing seasons varied from -42 (carbon uptake) to 34 (carbon release) g C m⁻². This result suggested that semiarid grassland might be a net carbon source even during the growing season depending on climate conditions.

Keywords: carbon cycle, photosynthesis, ecosystem respiration, semiarid grassland, Mongolia

Recent Active Peat Fire Situation in Kalimantan, Indonesia

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Fires in peatland in Kalimantan have become more severe in recent years. This may suggest peatland in Kalimantan is now toward destruction. This situation is made due to rapid deforestation and irreparable destruction of nature, such as Mega Rice Project (MRP) in central Kalimantan.

In this study, analysis of the most recent 10-year period (2002 to 2011) of MODIS hotspots data (fires) and precipitation in Palangkaraya and Pontianak was carried out to identify seasonal and spatial fire occurrence in Kalimantan under El Nino conditions. Most data was tallied every 10-days to analyze seasonal and spatial fire occurrence. Seasonal and spatial analysis results for severe fire years, namely 2002, 2004, 2006 and 2009, under El Nino conditions were as follows: the severest fire incidents occurred in mid October in 2006 under the driest conditions in both Palangkaraya and Pontianak. The second severest fires in occurred in 2002, under the second driest conditions. The severest fires for the MRP area and its vicinity occurred in late September in 2009 under the driest conditions only for Palangkaraya. The fourth severest fires occurred in 2004, when heavy rainfall in July delayed the onset of drought conditions. Fire activity in the last four-years in Central Kalimantan was more severe than that in West Kalimantan. This may be explained by different dry conditions of peat in both places, namely the peat in East Kalimantan could become dryer under the relatively long dry season (about 3-month) compared with peat under a shorter dry season (2/3-month) in West Kalimantan. Spatial analysis of the fire distribution of the severest fires that occurred in mid October in 2006 clearly showed a so-called a fire belt shape arising from severe fires that occurred mainly on the southern coastal peatland from West to Central Kalimantan. The typical West Kalimantan fires that occurred in early August 2009 coincided with the dry season period of West Kalimantan. Typical pre-dry season (caution) fires occurred in late June in 2009. Most of these fires occurred on peatland in West and Central Kalimantan. These results lead us to infer that the MRP was carried out in the worst part of Kalimantan from a climate perspective.

Keywords: peat fire, hotspot, dry season, Kalimantan, MRP

Observation of vegetation by GOSAT

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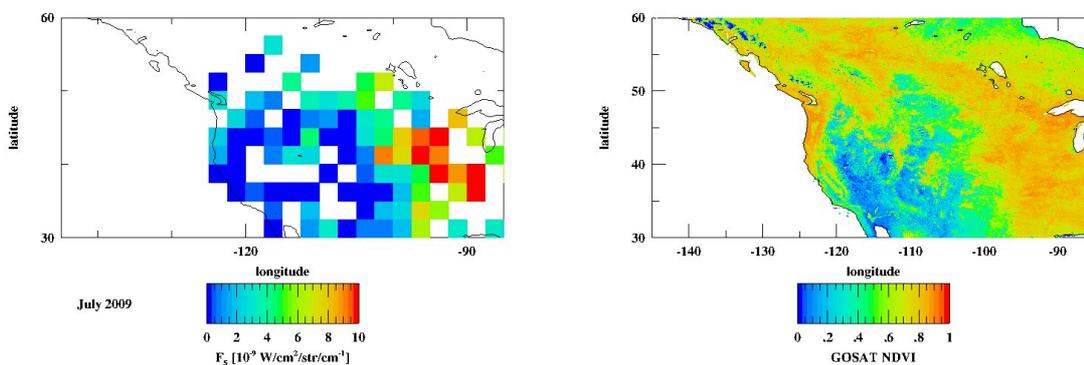
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The Japanese Greenhouse gases Observing SATellite IBUKI (GOSAT) is the first satellite that is designed specifically to measure greenhouse gases such as carbon dioxide and methane. After the launch in January 2009, GOSAT is operating successfully for more than 4 years. The main sensor of GOSAT is the Fourier Transform Spectrometer TANSO-FTS, which has 3 bands in the near-infrared and 1 band in the thermal infrared. Among these bands, TANSO-FTS has an observation window in oxygen A band at 0.76 micron to derive column amount of oxygen (equivalently, column amount of dry air or surface pressure), and to correct effects of clouds and aerosols on the retrievals of column amount of greenhouse gases. Recently, Joiner et al. (2011) and Frenkenberg et al. (2011) have shown that absorption lines in oxygen A band measured by TANSO-FTS can be used to detect chlorophyll fluorescence emitted by plants, and that GOSAT will be useful in wider fields of scientific research.

Chlorophyll fluorescence can be as intense as a few percent of TOA radiance at oxygen A band. Neglecting chlorophyll fluorescence could produce bias errors up to 2 ppm in the retrieved column-averaged mol fraction of carbon dioxide (XCO_2), depending on regions and seasons. Regionally or seasonally dependent bias errors in retrieved XCO_2 degrade the accuracy in inverting the amount of emission and absorption of greenhouse gases, which is the scientific goal of the GOSAT project. We are therefore developing an algorithm which is capable of retrieving XCO_2 and chlorophyll fluorescence simultaneously. Left panel of the figure shows 2.5 degree grid monthly averaged intensity of chlorophyll fluorescence in North America. It can be seen that the distribution of chlorophyll fluorescence is closely related to the normalized vegetation index (NDVI) shown in the right panel of the figure, which was derived from observations of TANSO-CAI (Cloud and Aerosol Imager) onboard GOSAT.

In addition to greenhouse gases, GOSAT is acquiring and processing observation data on vegetation such as chlorophyll fluorescence and NDVI. NDVI data are now provided to public users as a standard product of the GOSAT project. Long term observations of this kind of data are expected to be carried out by the GOSAT successor or similar satellites planned in several countries, and would be useful in studies on vegetation models.

Keywords: chlorophyll fluorescence, vegetation index



Allocation based robust methodology for simultaneous reproduction of carbon fluxes, LAI, and forest biomass

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The terrestrial carbon flux and storage are influenced by many environmental and physiological factors, such as drought, wind-storms, fire, human activities, vegetation types, forest age, or soil structure. To assess the terrestrial carbon flux and storage, terrestrial ecosystem models have been used for decades. Despite the long history of development and evaluation, however, there are still substantial uncertainties in their predictions. With the current state of performance, it is often the case that models need to be calibrated by adjusting predefined parameters for having agreement with observations.

Although calibration is necessary, seeming success of model based assessment of carbon flux often accompanies with the ill effect, substantial misrepresentation of storage. Because of its strong association with climate change, carbon fluxes have been more rigorously investigated by the terrestrial ecosystem modeling community. In practice, a number of model based analyses have paid attention solely on carbon fluxes and often neglected carbon storages such as forest biomass. As a result of this practice, model parameters are inevitably biased to carbon fluxes.

Against this ill practice, there are studies introduced methods for constraining both carbon flux and storage components. Richardson et al., 2010 is one of studies attempted to constraint both carbon fluxes and storages with the DALEC model using eddy covariance and multiple biometric observations. Although they successfully constrained model parameters, computational cost was significant with their approach: it involves several stage of model runs requiring 50,000 iterations for exploring parameter space for a single site. Their approach is effective for identifying physiological characteristics of a particular site, but is not ideal for analyzing multi-sites or large scale ecosystems. In that case, a more robust and simple methodology is needed.

Establishment of such a methodology may be more feasible by focusing on key physiological parameters. Such parameters have to be (1) strongly correlated to both carbon flux and storage so that simultaneous reproduction of carbon cycle components can potentially be achieved by manipulation of those parameters and (2) the fundamental backbone structure common to ecological modeling so that the same method can be applied to existing models. Ones that satisfy these requirements may be carbon allocation parameters. Carbon allocations can influence the plant growth by controlling the amount of investment acquired from photosynthesis, as well as carbon fluxes by controlling the carbon content of leaves (which turns into Leaf Area Index (LAI)) and litter, both are active media for photosynthesis and decomposition. Thus, LAI, gross primary productivity (GPP), ecosystem respiration (RE), and forest biomass can potentially be reproduced by allocation parameters.

Toward the full reproduction of carbon cycle, the present study explored the existence of such suitable balances of carbon allocations for several carbon flux and storage components: LAI, GPP, forest biomass, and the below- to above-ground biomass ratio. An experiment was performed with a widely used model, Biome-BGC. Through a process of testing the simultaneous reproducibility with the Biome-BGC, we evaluate and discuss consequences of commonly accepted practices in ecosystem modeling: (1) the carbon flux-oriented calibration and (2) application of fixed allocation parameter values for vegetation type. Appropriateness of fixed allocation parameter values was evaluated with a set of allocation parameter values estimated from the optimization.

Acknowledgments

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Reference

Richardson, A. D., et al., 2010. Estimating parameters of a forest ecosystem C model with measurements of stocks and fluxes as joint constraints. *Oecologia*, 164, 25-40.

Keywords: optimization, allocation, terrestrial ecosystem model, carbon fluxes, biomass

Change in the carbon emission from wild fire to the periodic variation of precipitation and temperature over Africa

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1 Introduction

In semi-arid regions of Africa, wildfire frequently occurs during dry season. The wildfires strongly constrain the structure, dynamics, and distribution of vegetation, and emit the large amount of carbonaceous aerosol. The atmospheric carbonaceous aerosol has ability to change climatic system, because it absorbs or reflects shortwave radiation. The change pattern of the carbon emission from wild fire to the fluctuation of precipitation was estimated using a dynamic global vegetation model. However, in order to change the cycle of sea surface temperature of the Atlantic and Indian Oceans, annual precipitation varies periodically in Africa. In addition, because the vegetation response to be sensitive to changes in temperature as well as precipitation, it is necessary to pay attention to the temperature as well. Our purpose is to estimate the change in the amount of carbon emissions from the fire to the periodic variation of annual mean temperature and annual precipitation in Africa.

2 Experiments

In this study, we estimate the rate of change of carbon emissions from wild fire for periodically changing precipitation and temperature using SEIB-DGVM (Spatially Explicit Individual Base Dynamic Global Vegetation Model). The study area is African continent (37N-34S, 17W-59S). The following three experiments were conducted. First, control experiments: the simulation was run for 13 years from 1997 to 2009. Second, there is no period of climate change: the average value of the annual mean temperature and annual precipitation from 1982 to 2009 were used as the input climate data set. Third, climate change 6, 10, 20 year period: the precipitation and temperature data, which changes periodically based on the standard deviation, were used as the input climate data set.

3 Results and Discussion

3-1. Control Experiment: The simulation was in good agreement with the spatial distribution of the annual carbon emissions from wild fire obtained from satellite observations GFEDv3. However, the mean values in each of the northern and southern hemispheres of carbon emissions were overestimated than the observed value. This is caused due to over-estimation of the biomass.

3-2. There is no periodic variation in annual precipitation and mean annual temperature: The Carbon emissions in the northern hemisphere are decreased, while it increased in the southern hemisphere. A tree coverage and biomass were increased because of tree mortality was reduced by extreme drought and high temperatures was eliminated. The reduced carbon emission in the northern hemisphere, because the probability of occurrence of fire was reduced by an increase in tree coverage. On the other hand, in the Southern Hemisphere, the amount of carbon emissions increased by an increase in biomass.

3-3. The annual precipitation and annual mean temperature varies in a cycle of 6, 10, and 20 years: the rate of change of carbon emission for the period change of precipitation is greater than temperature. In the northern hemisphere, there is a tendency to increase carbon emission in the short period. In the long period of climate change, there was very difference in carbon emissions by phase. In the northern hemisphere, the tree coverage showed a relatively low value when there is no variation in the periodic precipitation. As a result, carbon emissions increased due to the relatively high probability of fire.

4 Summary

A carbon emission from the current fire is affected by cyclical fluctuations climate (especially precipitation). In the Northern Hemisphere of Africa, the impact on carbon emissions from the change in tree coverage was strong in the short-period variation in precipitation. In the long-period variation of precipitation, there is a large difference in carbon emissions by phase.

Keywords: DGVM, carbon emission, fire, Africa

Impact of drought due to climate change on dry matter production and ecosystem function in tropical rain forests

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Since 1980's, climate changes caused by the El Nino-Southern Oscillation have been reported to result in the widespread death of trees due to droughts in many parts of the world. Tropical regions receive strong solar radiation, and tropical vegetation shows a strong feedback effect to carbon sequestration, water circulation, and climate formation. In addition, tropical forests are important ecosystems, and they act as a huge carbon sink because they cover 7-10% of the land area of the Earth and accumulate 40-50% of land vegetation carbon. In a biological community such as a tropical forest that consists of various species, response to changes in the physical environment depends on the operating functional group. A dynamic change in a particular functional group that plays a significant role in the biological community may influence the structure and ecosystem functions of the tropical forests. Although some model studies have been conducted on the response of vegetation to drought due to climate change, most of the models did not consider the ecophysiological mechanisms on the mortality process, and they could not be applied to the different climatic zones and types of forest vegetation. In this study, we predicted the impact of drought on dry matter production and ecosystem functions in tropical rain forests by using a spatially explicit individual-based biogeochemical model developed for predicting vegetation dynamics in response to climate change at the global level, such as global warming (SEIB-DGVM). In the model simulation, the estimated values, such as temperature and precipitation, for the global climate models were used in the vegetation dynamics model, and the dynamics of tropical rain forests for 200 years were described. The predicted result was compared with the meteorological and tree data, including the 1997/98 El Nino, of the tropical rain forests of Sumatra Island in Malaysia that were measured in 1997-2009 and was validated.

Keywords: drought, El Nino, tropical rain forests, ecological function, SEIB-DGVM

Evaluating future land-use change scenario in the negative fossil fuel emissions

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Bioenergy with Carbon Capture and Storage (BECCS) is a key component of mitigation strategies in the future socio-economic scenarios to keep mean global temperature rise below 2 degree Celsius above pre-industrial, which would require net negative fossil fuel emission in the end of 21st century. Large scale BECCS requires additional production of biofuels, which could potentially cause substantial emissions from the land-use change. Developing sustainable low carbon scenarios require careful consideration of the land-use implications involving large scale BECCS. I use a global terrestrial biogeochemical cycle model and a global crop model to evaluate effects of land-use change in RCP2.6, which is a scenario with net negative fossil emission aiming to keep the 2 degree Celsius temperature target for upcoming Intergovernmental Panel on Climate Change Fifth Assessment Report. Our analysis reveals that first generation bioenergy crop production would not be sufficient to achieve the required BECCS of RCP2.6 scenario even when I consider the higher fertilizer and irrigation use cases. It requires more than doubling the area for bioenergy crops around 2050 assumed in RCP2.6, however, such scenarios implicitly induce large scale land-use changes that emit significant amount of carbon from deforestation. Otherwise land use conflict with food production is inevitable.

Keywords: land-use change