Understory CO_2, sensible heat, and latent heat fluxes in a black spruce forest in interior Alaska

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In this presentation, we would like to introduce our recent publication, Ikawa et al., 2015, Agricultural and Forest Meteorology:
http://audioslides.elsevier.com//ViewerSmall.aspx?source=1&doi=10.1016/j.agrformet.2015.08.247
An open black spruce forest, the most common ecosystem in interior Alaska, is characterized by patchy canopy gaps where the forest understory is exposed. This study measured CO_2, sensible heat, and latent heat fluxes with eddy covariance (EC) in one of those large canopy gaps, and estimated understory fluxes in a black spruce forest in 2011 –2014. Then understory fluxes and ecosystem fluxes were compared. The understory fluxes during the snow-free seasons were determined by two approaches. The first approach determined understory fluxes as the fluxes from the canopy gap, assuming that fluxes under the canopy crown also had the same magnitude as the canopy gap fluxes. The second approach determined the understory fluxes by scaling canopy gap fluxes with a canopy gap fraction, assuming that only canopy gaps, which mostly constitutes the forest floor, contribute to fluxes. The true understory fluxes would be in between these two estimates. Overall, the understory accounted for 53 (39 –66) %, 61 (45 –77) %, 63 (45 –80) %, 73 (56 –90) %, and 79 (59 –98) % of the total net ecosystem productivity (NEP), gross primary productivity (GPP), ecosystem respiration (RE), sensible heat flux (H), and latent heat flux (LE), respectively. The ratio of understory NEP (NEP_U) to the ecosystem NEP (NEP_E) and similarly calculated LE_U/LE_E during the daytime increased with vapor pressure deficit (VPD) at low VPD conditions (~ 2000 Pa) at half-hourly temporal scale. At high VPD conditions, however, NEP_U/NEP_E decreased with VPD, whereas LE_U/LE_E was maintained at the high level even at high VPD conditions. Despite large ranges of the estimates for the understory contributions, we conclude that the understory plays an important role in the carbon and energy balances of the black spruce ecosystem, and their contribution highly depends on the level of VPD.

Keywords: carbon cycle, boreal forest, understory

CH_4 Flux of Asian Terrestrial Ecosystems Based on a Soil Respiration Chamber Network

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Methane (CH_4) is the second important greenhouse gas (GHG) after carbon dioxide (CO_2), because CH_4 has a relative global warming potential 28-36 times of CO_2 at a 100-yr time horizon. Moreover, atmospheric CH_4 concentration has doubled since 1800 and contributes about 20% to the global radiative forcing. Recently, a process-based coupled biogeochemical model estimated that CH_4 emission from global terrestrial ecosystems was 144.39±12.90 Tg C/yr with an increasing rate of 0.43±0.06 Tg C/yr between 1981 and 2010 (Tian et al. 2015). The dominant sources of CH_4 are nature wetlands and rice fields.
Asian wetlands occupy vast areas from tropical peat swamp forests in Southeast Asia to boreal marsh in Northeast Asia, and as well as alpine meadow on the Tibet Plateau. Furthermore, Monsoon Asia is the largest rice-producing area. The countries of this region together produce 90% of the global output of rice. Thus, Asia plays an important role in the regional exchange of CH_4 between terrestrial ecosystems and the atmosphere. However, currently Monsoon Asia is under various pressures such as land-use and climate changes. Quantifying CH_4 balance is helpful for understanding their response and feedback to the changing world, and simultaneously is critical for setting targets for GHGs (e.g. CO_2, CH_4, N_2O) emission reductions and to identify and promote mitigation strategies. This talk will present CO_2/CH_4 fluxes and their controls of a meadow peatland on Tibet Plateau, a larch forest in central Japan, and a tropical rainforest in the Peninsular Malaysia by using multichannel automated chamber systems.

Keywords: Chamber network, CH4 flux, Larch forest, Tibet Plateau wetland, Tropical rainforest

Estimation of carbon translocation and allocation in Siberian larch saplings at Mongolian forest using ^{13}C pulse-labeling experiment

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Tree-ring analysis has been conducted in Mongolian northern forest area to investigate tree response to rapid environmental change in recent years. The results showed that severe drought events induced decrease in Siberian larch tree growth in recent years. However, physiological response of larch trees to environmental change has not yet been well understood in this region. In addition, it is still not clear how tree allocates assimilated carbon in tree body, although it is necessary to interpret tree-ring data.
Thus, we conducted ^{13}C pulse-labeling experiment using larch tree saplings in 2014 summer at KT site (47.7N, 107.6E) to estimate carbon allocation in trees and physiological response to environmental change in this region. Larch tree saplings were labeled by $^{13}CO_2$ in the middle of June and the beginning of August. The labeled trees were sampled for the period from 1 week to 1 year to investigate carbon allocation in tree body.
Most of the ^{13}C assimilated in the middle of June was kept in the needles until just before defoliation, and the carbon allocation to other tree parts (e.g. branches, stem and roots) was small. Assimilated ^{13}C in the beginning of August rapidly translocated from needles to other parts, and the carbon allocation to the roots was large compared to ^{13}C assimilated in June. The result probably indicates carbon accumulation in autumn for growth in the following year. Our results also showed a possibility that ^{13}C fixed in August preferentially allocated from storage pools to needles for growth of new shoots in the following spring compared to ^{13}C assimilated in June.

Keywords: Mongolia, Larch tree, 13C pulse-labeling, Carbon allocation

Effects of elevated CO_2 levels and N fertilization on biomass and C and N contents of rice: Insights from Tsukuba FACE

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Rice is a staple crop in monsoon Asia, and its world production is the second largest next to that of maize. Rice paddies under submergence are an anthropogenic source of methane as a potent greenhouse gas. According to the fifth IPCC assessment report, rice paddies account for approximately 11% of the anthropogenic methane emissions. It is of great concerns how the increasing atmospheric CO_2 levels (eCO_2) affect rice production and rice paddy methane emissions in the near future. In many cases, nitrogen (N) fertilizers are applied to rice paddies, and the N cycle in rice paddy ecosystems is closely interacted with the carbon (C) cycle. To enhance the predictability of rice production and C and N cycles in rice paddy ecosystems in the future, effects of eCO_2 and different N availability on C and N cycles in rice paddy ecosystems and these mechanisms should be unraveled.
A free-air CO_2 enrichment (FACE) experiment in an open field enables to elucidate responses of actual ecosystems to eCO_2. The National Institute for Agro-Environmental Sciences, Japan, had operated a FACE facility (Tsukuba FACE) in Tsukubamirai City, Ibaraki Prefecture since 2010. Single cropping of paddy rice is conducted with the following agricultural practices; submersion in late April; fertilization and puddling in middle May; transplanting of rice seedlings in late May; continuous submergence until the drainage in middle to late August; harvesting in middle to late September; a fallow season with bare soil and rice residues until the next spring; and several tillage events with a mixing depth of approximately 15 cm during the fallow season. Four rectangular bays are used for experiments. A FACE plot is set in each bay, accompanied by an ambient plot. Each FACE plot is equipped with an octagonal ring with a diameter of 17 m for pure CO_2 release. The FACE equipment automatically regulates CO_2 release to achieve the average target CO_2 levels, 200 ppm above the ambient level. Treatments other than CO_2 are N fertilization (0N, no application; SN, 8 g N m^{-2}; HN, 12 g N m^{-2}), temperature (ambient, +2°C for floodwater), and rice cultivars.
Five-year data (2010–2014) of Koshihikari, a staple cultivar in this region, showed that the aboveground biomass of rice was increased by eCO_2 for all the N treatments (0N, +8%; SN, +10%, HN, +11%). The brown rice yield at SN and HN were also increased by eCO_2 (SN, +12%; HN, +11%), whereas that at 0N did not respond to eCO_2. Thus, the harvest index (the ratio of yield to aboveground biomass) of SN and HN were unchanged by eCO_2, but that of 0N was decreased by 5% under eCO_2. This result implies that the CO_2 fertilization effect does not reach to grains under low N availability. The seasonal methane emissions were increased by 5% (SN) under eCO_2. In the presentation, study results on the carbon and nitrogen contents and the allocation of biomass between shoot and root under eCO_2 and different N availability will be shown. It is expected that such the knowledge gives good insights to research on responses of C and N cycles in terrestrial ecosystems to eCO_2.
This study was supported by Grant-in-Aid for Scientific Research, Nos. 22248026, 24114711, and 2625206, provided by the Japan Society for the Promotion of Science. Tsukuba FACE was established and maintained by ''Development of technologies for mitigation and adaptation to climate change in Agriculture, Forestry and Fisheries'', a project provided by the Ministry of Agriculture, Forestry and Fisheries, Japan.

Keywords: FACE, Rice, Rice yield, Biomass, Carbon cycle, Nitrogen cycle

Mapping of year-to-year deforestation area in insular Southeast Asia

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Accurate mapping of year-to-year variability of the spatial distribution of deforestation is important to evaluate the biodiversity, ecosystem functions and services in tropical ecosystems under rapid human activities. In Malaysia and Indonesia, deforestation and vegetation plantation establishment by planting oil palm or acacia have continued. Here, we examined the ratio of the number of days of Terra and Aqua MODIS satellite-observed daily green-red vegetation index (GRVI) < 0 to number of days of all GRVI with high quality (mainly without cloud contamination) for each year from 2001 to 2014 in insular Southeast Asia. We found that the area of deforestation and vegetation recovery were detected each year in southern part of Malay Peninsula, lowland area in Sumatra, and Sarawak and Central Kalimantan in Borneo. Our finding suggests that the biodiversity, ecosystem functions and services may be deteriorating in large areas in Malaysia and Indonesia.

Keywords: satellite observation, deforestation, year-to-year variability, insular Southeast Asia

Large scale evaluation of decadal forest biomass changes using repeated airborne LiDAR observations in northern Japan.

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Valid estimation of terrestrial carbon cycle depends strongly on the accurate estimation of changes of global forest carbon stock. To estimate forest biomass changes, its vertical structure is critical information, and airborne light detection and ranging (LiDAR) is expected to be an effective method to measure. We examined the feasibility of estimating forest biomass changes using two airborne LiDAR measurements of forest height acquired 10 yr apart (2004 and 2014) over the Teshio Experimental Forest (225 km^2) of Hokkaido University in northern Japan. Whole the area of the experimental forest was divided into 23,502 cells having 1 ha cell size, and the decadal change of the mean canopy height (ΔMCH) was obtained for each cell using the two digital surface models observed in 2004 and 2014, then the ΔMCH was converted into the biomass changes using a linear relationship obtained from the relationship between MCH and the biomass for the experimental forest (Takagi et al., 2015). Estimated decadal biomass change was validated using the ground observation obtained from long-term forest biomass observation plots and artificially logged-plots during the period.
Decadal net biomass change had large spatial variation ranging from +35 to - 50 MgC ha^{-1}, even after excluding the artificially logged plots during the period. The average was 4.06±6.44 (SD) MgC ha^{-1}, where the photosynthetic biomass increase was 11.7±4.79 MgC ha^{-1} and the tree carbon decrease, caused by coarse woody litter or tree falling, was 8.71±4.08 MgC ha^{-1}. These values were comparable with the results obtained from ground surveys or tower flux observations operated in Hokkaido, northern Japan. The decadal net biomass change was significantly lower at high elevation, north facing slope, large tree height variance, and coniferous forest, and significantly higher at south facing slope, deciduous forest, and secondary forest. The photosynthetic biomass increase was linearly correlated with the decadal average of the MODIS Vegetation Indices, with r^2=0.64 for NDVI and 0.52 for Green ratio, which implies the application of MODIS Vegetation Indices to further large scale estimation of forest biomass change using satellite observation.

Keywords: Airborne LiDAR, Forest, Biomass change

Vertical profile of photosynthetic functions and its seasonal variation in a cool temperate forest

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Vegetation activity is affected by many kinds of environmental stresses. To detect those environmental stresses on land ecosystem' photosynthesis remotely, spatially-widely and instantaneously, remote sensing (RS) technics for chlorophyll fluorescence (ChlF) have been developed recently. However, such RS watches only the top of canopy, and may miss the activity under the canopy where much of biomasses are still existing. This leads to an estimation error on the physiological state of ecosystem. To make sure how much of estimation error may exist, therefore, it is necessary to investigate the vertical profile of photosynthetic stresses.
To reveal the vertical profile on the relationship between the photosynthetic stresses and environments, diurnal courses of light, temperature and fluorometric parameters were measured in an evergreen coniferous forest (*Cryptomeria japonica* and *Chamaecyparis obtusa*; 36°08'N, 137°22'E, 800m a.s.l) and an deciduous forest (*Quercus crispula Blume* and *Betula ermanii*; 36°80'N, 137°82'E, 1420 m a.s.l) in Takayama, Japan in June, August, and October in 2015. The measurements were conducted at three heights on the eddy flux towers at both sites. The photosynthetic active radiation and fluormetry parameters were detected by two fluorometers (FlourPen FP100 and FluorPen FP100-MAX, Photon Systems Instruments, Brno, Czech Republic) five times in a sampling day. In addition, leaf temperature also measured simultaneously by radiative thermometer (Radiation thermometer B, Shinwa).
As a result, quantum yield of the foliage in upper layers (21 m) declined in the midday more than those in middle (18 m) and bottom (13 m) layers for cedar leaves in the coniferous forest. On the other hand, in deciduous forest, there was little differences in diurnal course of quantum yield of birch leaves among three layers. This smaller vertical effect in deciduous forest is probably due to lower photosynthetic capacity of photosynthesis of birch foliage under canopy.

Keywords: Chlorophyll fluorescence, Environmental stress

Phenological changes in leaf optical properties of canopy trees and canopy surface reflectance in a cool-temperature deciduous broadleaf forest

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The radiation reflectance from the canopy surface is used in the remote sensing of vegetation structure and biochemical properties, including photosynthetic capacity, water use and photoinhibition. The canopy reflectance is strongly affected by leaf are index (LAI) as well as leaf reflectance and transmittance of radiation in the canopy. Deciduous forest is characterize by the remarkable change in canopy structure such as leaf expansion in spring and leaf fall in autumn. In addition, leaf optical properties (spectral reflectance, absorption and transmittance of radiation) of the deciduous trees also changes according to the leaf growth and senescence because the leaf optical properties characterize leaf biochemical components, such as chlorophylls, carotenes, anthocyanins, nitrogen, cellulose, lignin and water, and anatomical structures.
The forest at Takayama site is a cool-temperate deciduous broadleaf forest on the northwestern slope of Mt. Norikura, in central Japan. The forest canopy is dominated by *Quercus crispula* Blume and *Betula ermanii* Cham. In this forest, we measured the leaf optical properties of these dominant trees during the growing season, from budburst in mid-May to senescence at beginning of November. The measurements were conducted in 2004, 2005, 2006 and 2010. The leaf reflectance in the red (620-670 nm), blue (459-479 nm) and green band (545-565 nm) dropped in the beginning of growing period and increased in senescing period. Near-infrared reflectance (841-876 nm) increased in the growing period. Then these leaf-level phenology was examined with the seasonal change of air temperature, and also up-scaled to canopy-level by a radiative transfer model SAIL to examine the canopy-level spectral reflectance observed at the same site from the leaf and canopy ecophysiological point of view.

Keywords: deciduous forest, phenology, remote sensing

Tracing the de-epoxidation reaction of the xanthophyll cycle in natural beech leaves using hyperspectral reflectance

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The epoxidation state of the xanthophyll cycle pigments (EPS) is a useful measure of short-term changes in photosynthetic light-use efficiency and it is suggested as the best indicator for evaluating the state of xanthophyll cycles (Gamon et al. 1990). In order to calculate EPS, we have to measure the concentrations of the three xanthophyll cycle pigments (violaxanthin (V), antheraxanthin (A) and zeaxanthin (Z)) using high performance liquid chromatography (HPLC) (Thayer and Bjorkman 1990). However, its application is restricted to leaf scale and it is difficult to expand into large-scale monitoring.
On the other hand, remote sensing is one of the alternative strategies and the hyperspectral index, photochemical reflectance index (PRI) has been applied for evaluating light use efficiency in the previous studies (Filella et al. 2009; Gamon et al. 1992; Gamon et al. 1997; Sha et al. 2014; Stagakis et al. 2014). However, few studies have paid attention to the differences between sunlit and shaded leaves of deciduous plants and the relationship between PRI and photosynthetic light use efficiency is weak for deciduous species (Nichol et al. 2000).
In this study, we explored the ability of PRI to trace EPS based on a series of experiments with only light stress and inhibited treatments. Furthermore, the novel hyperspectral indices, a differential type of index using reflectance derivatives at 677 and 803 nm, was developed.
Results revealed that PRI had low correlations with the EPS of deciduous leaves, especially for sunlit leaves. On the other hand, the newly proposed index was applicable for both. Furthermore, it was applicable for various conditions generated by the inhibitor experiments or the samples obtained from other deciduous species (*Lindera umbellate*, *Clethra barbinervis*, *Viburnum furcatum*, *Eleutherococcus sciadophylloides*, *Quercus crispula* and *Acer japonicum*).

Keywords: EPS, hyperspectral reflectance, xanthophyll cycle

Comparison of the simulated global the canopy scale sun-induced chlorophyll fluorescence and satellite-based SIF measurements

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Recent studies show that the terrestrial plant canopy sun-induced chlorophyll fluorescence (SIF) can be observed from satellites and the several SIF products have been produced. The potential application of these new products is being investigated. In this study, we performed a canopy and leaf level radiative transfer simulation to understand how leaf-level SIFs from sunlit and shaded leaves contribute to the canopy scale SIF that is observed by satellites. We also investigated how the sunlit and shaded SIF contributions varied with the observed angles. The results showed the large variations in sunlit and shaded leaf contribution regarding the observation angles. In particular, the SIF observation near the solar disc contains more sunlit leaf SIF information. We also found that the SIF emission after multiple scattering within canopy cannot be negligible.

Keywords: remote sensing, SIF, plant canopuy radiative transfer

Estimating evapotranspiration from seasonal wetlands in north-central Namibia based on satellite data fusion and VI-Ts method

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Estimation of evaportanspiration (ET) with highly spatio-temporal resolution is essential for various environmental applications such as plant dynamics monitoring, agricultural management, and assessment of human impact on local water environment. In such cases high spatial resolution (several tens to hundreds of meters) is required to describe heterogeneous land use or land cover (LULC) finely. However, existing researches for ET estimation by using land surface models or remote sensing have been mostly provided with insufficient spatial resolution (several tens to hundreds of kilometers). Thus we implemented ET estimation with highly spatio-temporal resolution based on three types of satellite images (AMSR series, MODIS, and Landsat ETM+) over a study site in north-central Namibia, where seasonal wetlands appear in rainy season.Our proposed method calculate ET from two ground source (one is surface water with vegetation, and the other is soil) separately, to appropriately describe the heterogeneous seasonal wetlands. It mainly consists of two phases: 1) satellite data fusion by using “database unmixing” (Mizuochi *et al.*, 2014) to obtain daily 30-m-resolution water maps, and 2) estimation of weekly ET with 30-m-resolution by VI-Ts method with MODIS short-wave radiation and land surface temperature (Ts) products. Although the VI-Ts method has been originally designed for a scatter plot between vegetation index (VI) and Ts to estimate air temperature and theoretical maximum soil temperature, we insteadly applied it between water index (MNDWI) and Ts. This application enabled us to evaluate ET from surface water and soil separately within sub-pixel scale (i.e. less than 30-m-resolution). Specific procedure of this phase is as follows: firstly, we calculated ET from soil based on the VI-Ts method and radiation and heat balance equation. Secondly, we calculated ET from surface water based on complementary relationship and Jarvis conductance model. Finally, we calculated total ET in each pixel as weighted-average of the soil ET and the surface water ET by water fraction (WF) of each pixel.We calculated spatio-temporal ET distribution in three test sites of north-central Namibia (each site has area of 5.3 kmx5.3 km) from 2003 to 2013, and then compared it with both in-situ flux data and MODIS ET product (MOD16), which is retrieved by Penman-Monteith equation. Also, we calculated 1) available energy (Q), 2) evapotranspiration fraction (EF), 3) surface water ET contribution (WC) within total ET, and 4) WF, to investigate the features of ET in seasonal wetlands.The estimated ET is consistent with the in-situ flux data, and the variation of ET from dry- to rainy-season was described well. Comparison among Q, EF, WC and WF revealed that in seasonal wetlands most of Q was used as ET, and most ET came from surface water source. Achieved ET in high spatial resolution could well describe the heterogeneous seasonal wetlands, whose scale is several tens to several hundreds of meters and is not detectable by MOD16. However, comparing with MOD16, our proposed method tends to overestimate ET. This means the necessity of the improvement in algorithm and more careful validation.The provided method enables us to describe ET from highly heterogeneous land surface, and it is applicable to the other regional-scale research over the world. Our next work will focus on the assessment of impact of anthropogenic LULC change on ET of the seasonal wetland, by changing scenarios of parameters in VI-Ts and Jarvis conductance model.

Keywords: database unmixing, VI-Ts method, seasonal wetlands

Optimization of a terrestrial ecosystem model by data assimilation: demonstrating flexibility of the particle filter

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Although data assimilation is widely used for optimization of simulation models, due to complexity, terrestrial ecosystem models have not become one of main targets of data assimilation. In this study, using the particle filter, a method of data assimilation, we show that a terrestrial ecosystem model with complex structure and abrupt behavior can be optimized. As a case study, leaf onset and offset phenology, abrupt behavior in forest ecophysiology, of deciduous trees in a terrestrial ecosystem model was optimized. Using satellite-based leaf area index, here we show the results of data assimilation where the set of model parameters were optimized.

Keywords: ecosystem modeling, data assimilation, terrestrial ecosystem

Impacts of leaf wetness on forest carbon cycle under air pollution

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Tropospheric ozone impairs forest productivity and causes stomatal sluggishness, i.e., a delay in stomatal responses to fluctuating stimuli, which can change the carbon and water balance of forests. Nevertheless, this effect is not included in the current land surface model. In this study, we examine the effects of ozone-induced stomatal sluggishness on carbon assimilation and transpiration of temperate deciduous forests in the Northern Hemisphere by combining a multi-layer land surface model (SOLVEG) and a global atmospheric chemistry model. SOLVEG considers the processes of changes in the maximum rate of carboxylation (V_{cmax}) and the stomatal conductance (g_s) due to ozone uptake by leaves depending on canopy wetness level. The results demonstrate that ozone-induced stomatal sluggishness decrease water use efficiency, i.e., the ratio of net carbon assimilation to transpiration, of temperate deciduous forests at high ozone concentration areas. However, this effect was small in the regions with long wet spell of forest canopy due to high annual rainfall frequency, indicating that the ozone effect on forests also depends on canopy wetness period. Since wet spell in Asian region is expected to become shorter in future climate scenario, ozone-induced stomatal sluggishness and net carbon assimilation decline enhanced by long dry period under severe air pollution may change water and carbon cycle of forest ecosystems.

Keywords: Forest carbon cycle, Air pollution, Canopy wetness

Current status of data-driven estimation of terrestrial carbon and energy fluxes using eddy-covariance network and remote sensing data

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The terrestrial biosphere plays important roles in regional and global energy and carbon cycles through biogeochemical and biophysical processes, in turn affecting the trajectory of climate change. Despite the importance of this issue, model intercomparison efforts have revealed large and persistent uncertainties in CO_2 fluxes among terrestrial biosphere models. Reducing uncertainties in terrestrial carbon cycle simulation is a challenging task because of insufficient observed CO_2 fluxes, which serve as references for refining terrestrial biosphere models at regional and global scales. Recently, the network of eddy-covariance observation has increased, and more data have become available to public. These datasets allow data-driven modeling (empirical upscaling) of terrestrial CO_2 and H_2O fluxes, and their application has shown significant progresses. Since data-driven models rely on the statistical relationship between observed fluxes and explanatory variables, the estimated flux is independent from terrestrial ecosystem models. Therefore, the results provide a new data constraint to terrestrial carbon and energy cycle communities.
In this presentation, we introduce an overview and applications of data-driven modelling to terrestrial biogeochemical studies. We used regional and global networks of eddy-covariance observations (e.g. AsiaFlux and FLUXNET) and remote sensing as the forcing of data-driven model, and conducted various applications using them. First, we will show the methodology and algorithms of data-driven model. Second, we will show the applications of the resulting data: i.e., spatio-temporal variability in terrestrial CO_2 flux (Saigusa et al. 2010; Ueyama et al. 2013) and energy balance (Ueyama et al. 2014). Third, we will present evaluation of data-driven models with an assimilation of atmospheric CO_2 from GOSAT Level 4A product (top-down approach) (e.g. Kondo et al. 2015). Fourth, we will demonstrate that regional/global CO_2 and H_2O fluxes upscaled by data-driven models can be used to refine terrestrial ecosystem models (e.g. Ichii et al. 2009).

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Keywords: Terrestrial biosphere, Upscaling, Material Cycle

Evaluation of interannual variations in primary productivity by a simple vegetation model

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In a terrestrial ecosystem, heterotrophs depend on primary productivity, which is affected by climate change. Various types of process-based models have been developed to estimate primary productivity, resulting in growing understanding about the roles of terrestrial ecosystems in material circulations and energy flows. However, meteorological constraints on phenology that influence seasonal changes in primary productivity are still uncertain. Prognostic leaf growth models are possible to contribute to interpret the mechanisms. We developed a process-based vegetation model driven by simple climate variables to estimate primary productivity. Using this model, we examined the spatiotemporal variability in primary productivity and the timing of leaf onset and fall.

This model consists of four submodules: (1) energy and water balance, (2) water-carbon exchange, (3) allocation of assimilated carbon, and (4) phenology. Photosynthesis and evapotranspiration rates are computed forced by simple meteorological variables (*i.e.* air temperature, solar radiation, precipitation, relative humidity, and wind speed) at a 30-min interval in (1) and (2). The computed primary productivity is then transmitted to (3) and (4) wherein leaf growth is calculated at a one-day interval. Leaf growth is computed based on meteorological resources and allocations of assimilated carbon. The proposed model considers the differences in biophysical and ecophysiological traits among plant functional types.

First, we examined interannual variations in gross primary productivity (GPP) at some flux tower sites. We used meteorological and biochemical data observed at flux towers and those archived in FLUXNET. Second, we evaluated spatiotemporal variability in GPP in Monsoon Asia. Gridded meteorological data from general circulation models (GCMs) were spatially interpolated to the resolution of vegetation distribution data. We examined the influences of the interannual variations in climate on GPP and leaf phenology.

The proposed model captured seasonal changes in the measured GPP per site. The estimates of interannual variations were rather comparable to the measurements. For example, the reduction in GPP due to a cool and wet summer in 2003 at Fujiyoshida was greatly reproduced. Although the model estimated a low GPP at Appi in the same year, the measured value was the greatest in 2000–2006. This discrepancy occurred possibly because the model ignores species-specific traits. However, the model comprehensively reproduced temporal changes in GPP in response to climate variations. The results of the experiment suggest GPP at the peak of leaf growth affects the growth after that and therefore annual GPP.

The total annual GPP in Monsoon Asia varied in response to interannual climate variations. There were some areas, where the interannual variability in GPP was large. This result shows that the GPP in these areas are sensitive to climate variations. In this presentation, we will discuss how climate variability affects the GPP through leaf phenology.

Keywords: interannual variation, simple climate variable, phenology

Integrated modeling of greenhouse gas budget of terrestrial ecosystem

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Variation in greenhouse gas budget of terrestrial ecosystem can act as a positive or a negative feedback process to the human-induced climate change. It is necessary to estimate the greenhouse gas budget of terrestrial ecosystems with as high accuracy as possible, for developing an emission scenario, for making a projection with earth system models, for predicting climate change impacts, and for evaluating mitigation options. Global terrestrial models have mainly accounted for atmosphere-ecosystem exchange of CO2, which has the largest contribution to radaitive forcing change. Recently, several models have been developed to simulate terrestrial fluxes of CH4 and N2O. Dynamic Land Ecosystem Model (DLEM) and TRIPLEX-GHG are developed in the United States and Canada, respectively, and in Japan, Vegetation Integtated SImulator for Trace gases (VISIT) has been developed. In terrestrial ecosystems, CH4 and N2O fluxes have a more variety of emission sources and show greater spatial heterogeneity, making it more difficult to simulate them in comparison with CO2 fluxes. Namely, CH4 or N2O can determine the total greenhouse gas budget in several regions. Previous studies have implied that terrestrial ecosystems have absorbed CO2 through time, whereas CH4 and N2O emissions have been increased as a result of human land-use and climate change. Therefore, to evaluate the total effect of terrestrial ecosystems, it is necessary to include the contributions of CH4 and N2O. In fact, the Global Carbon Project began to conduct global syntheses of CH4 and N2O, in addition to CO2. Finally, I make discussions on the current status and problems related to this topic.

Keywords: Greenhouse gas, Climate change, Terrestrial ecosystem

