Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACG30-P01 Room:Convention Hall Time:May 25 18:15-19:30

Estimation of carbon cycle in a cool-temperate coniferous forest by continuous monitoring of carbon isotopic ratio

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In recent years, carbon assimilation has been estimated at various vegetation and forests are expected as carbon reservoir for the future climate changes. In a forest ecosystem, gas-exchange processes are complicated and difficult to estimate carbon flows because leaf, trunk, root and soil have distinctive gas-exchange characteristics and are interactively affected by environmental factors within a canopy. Fluxes and concentrations of $^{12}CO_2$ isotope compositions provide information about ecosystem physiological processes and their response to environmental variation. We continuously measured the concentrations of $^{12}CO_2$ and $^{13}CO_2$ inside the automated closed dynamic soil chambers and the surrounding atmosphere of a cool-temperate coniferous forest near Mt. Fuji in Japan (AsiaFlux site code:FJY) using a tunable diode laser spectrometer (TDLS: G2101i, Picarro Inc.). The δ13C of the atmospheric CO_2 were fluctuated according the changes of CO_2 concentration and fluctuations of the carbon isotope signal from soil respired CO_2 ($\delta^{13}CR_s$) was not detected, although Keeling plots to estimate $\delta^{13}CR_s$ were very sensitive and the results were very scattered.

To understand carbon flows in a tree, we carried out in situ ^{13}C pulse-labelling experiments for a mature pine tree (*Pinus densiflora*, Tree height: 20m) at the FJY site. The experiments were carried out September 2012, December 2012, and July 2013, covering the canopy of the tree by a plastic film chamber and introducing $^{13}CO_2$ into the labelling chamber. The internal $^{12}CO_2$ and $^{13}CO_2$ was monitored by the TDLS to calculate a carbon assimilation by the tree during the labelling experiments. Carbon efflux from a trunk surface were monitored by the TDLS using four closed dynamic trunk chambers installed in different heights (15.5, 11.1, 7.3 and 3.8m height) of the tree. The carbon flow speed were estimated from the arriving time of $^{13}CO_2$ pulse to the trunk chambers. The pattern of labelled $^{13}CO_2$ efflux in winter was different from other seasons. The speeds ranged from 0.04 to 0.24 m/hr and relatively slow in winter. The amount of carbon respired from the trunk surface were ranged 14-20% of the assimilated carbon. In winter, the tree respired carbon from relatively upper trunk surface and lower in other seasons.

Keywords: forest, carbon cycle, isotope, laser spectrometry, carbon dioxide, respiration

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Methane dynamics in a temperate forest revealed by plot-scale and ecosystem-scale flux measurements

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Soils play important roles as CH_4 sources and sinks. CH_4 is produced in anoxic environments, including submerged soils, by methanogenic bacteria. On the contrary, CH_4 is oxidized by methanotrophic bacteria in upland soils. In general, forest soils are recognized as the efficient sinks for atmospheric CH_4, because of their CH_4 oxidation capacity in water-unsaturated soil (Le Mer and Roger, 2001). However, we hypothesized that forest ecosystems, especially in wet warm climates such as Asian monsoon climate, are not always CH_4 sink. In this study, we examined the CH_4 dynamics in a temperate Asian monsoon forest (Kiryu Experimental Watershed: 35^{o}N, 136^{o}E), which included wet areas along riparian zones within the watershed. In order to reveal the spatio-temporal variations of CH_4 fluxes, we combined multi-point plot-scale CH_4 flux measurements using chamber methods and ecosystem-scale CH_4 flux measurements using a micrometeorological method, relaxed eddy accumulation (REA) method (Businger and Oncley, 1990; Hamotani et al., 1996, 2001).

Intensive manual chamber measurements of CH_4 fluxes at 60 points in the wet areas and within the water-unsaturated forest floor, respectively, showed that the wet areas had a greater spatial and temporal variability of CH_4 fluxes than the forest floor. This indicates that accurate consideration of CH_4 fluxes from any wet areas is important in order to evaluate the CH_4 budget within the forests. From biweekly continuous manual chamber measurements of CH_4 fluxes at 9 points in the wet areas and the forest floor, respectively, hotspots of CH_4 emissions were observed during summer and fall immediately after intensive precipitation in the wet areas. On the other hand, in the forest floor, seasonal variations of CH_4 fluxes were not simply associated with temperature variations. In contrast, CH_4 absorption increased at some measurement plots in spring before intensive summer rainfall. In addition to the manual chamber measurements, we observed the environmental responses of CH_4 fluxes at a half-hourly time resolution, by using automated chamber measurements at three plots on the water-unsaturated forest floor. We found that the CH_4 absorption flux was greatly weakened by summer intensive rainfall, but recovered and peaked after rainfall as the soil water content decreased. The responses of CH_4 fluxes to rainfall were different for each plot. In a dry soil plot with a thick humus layer, CH_4 fluxes decreased abruptly at the peak of rainfall intensity, and it increased gradually after rainfall. In a wet soil plot and a dry soil plot with a thinner humus layer, such abrupt decreases in CH_4 fluxes were not observed, and CH_4 fluxes gradually switched from a sink to neutral following rainfall. Simultaneous measurements of CO_2 fluxes provided useful information when considering the controlling factors affecting complex CH_4 fluxes in terms of gas diffusivity and microbial activity.

The ecosystem-scale CH_4 flux measurements revealed that the Japanese cypress forest switched seasonally between being a sink and source of CH_4, and the pattern differed year by year. CH_4 fluxes tended to be a source during summer and fall, and switched to a sink during dry period. At hourly to daily timescales, the CH_4 fluxes were sensitive to rainfall; rain events increased CH_4 emission, decreased CH_4 absorption, or shifted CH_4 absorption to CH_4 emission. The results show that the temperate forest containing riparian zone acted as a CH_4 source seasonally, through the increased CH_4 emission in the wet areas and/or the decreased CH_4 absorption on the water-unsaturated forest floor in response to changing soil temperatures and/or the soil water status. The Asian monsoon rainfall was found to strongly influence temporal variations in CH_4 fluxes at both plot-scale and ecosystem-scales.

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Response of Siberian larch in Mongolia to environmental variability for the last century

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Mongolian forest locates the southern boundary of Siberian Taiga forest. Patchy forests are observed only on the permafrost in moisture area in Mongolia where annual precipitation exceeds about 300mm. Therefore, this means moisture condition is a major factor controlling forest distribution. Recently, increase in temperature and decrease in precipitation have been reported in large area of Mongolia (Batima, 2006), and that these environmental changes may be a potential trigger tree mortality, change in forest distribution and future thaw of permafrost. In this study, we selected five areas showing different moisture condition and growth environment, Terelj (47N, 107E) in Khenty mountain region, Tsagaannuur (51N, 99E) and Hatgal (50N, 100E) near Khuvsgul Lake in the northern forest area, and Tariat (48N, 100E) and Uyanga (51N, 102E) in Hangayn mountain region respectively. Tree-ring cores were collected from Siberian larch and tree-ring width was measured for each areas. Carbon isotope ratio in tree-rings were analyzed to understand tree response to environmental variability for two areas of these.

Tree-ring width at Terelj negatively correlated with temperature and positively correlated with precipitation, and carbon isotope ratio positively correlated with temperature and negatively correlated with precipitation of previous and current summer. Especially, tree-ring width shows more clear correlation with precipitation in previous summer than that in current summer, whereas carbon isotope ratio shows more good correlation with precipitation in current summer than that in previous summer. These results suggest that stem growth depends on the moisture condition in previous year, while tree-ring is formed with carbon assimilated in the current year. Siberian larch showed very narrow ring width in recent years (after 1997) with very high carbon isotope ratio at Terelj, suggesting severe drought stress. On the other hand, tree-ring width and carbon isotope ratio in northern forest area did not show clear correlation with climate parameters. This results imply that trees in Tsagaannuur and Hatgal grow under relatively wet condition compared to trend at Terelj. Narrow ring width and high carbon isotope ratio found for Terelj was not observed trees in northern forest area.

Keywords: Monoglia, Larch, Tree-ring, Carbon isotope ratio, Drought stress

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In situ measurement of soil carbon monoxide flux in temperate forest

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Carbon monoxide plays an important role in the tropospheric chemistry via its reaction with the OH radical. Soil uptake of CO is a sink of secondary importance, except for the chemical reaction with the OH. However, no reports are available on soil CO flux continuously measured in the field of forest. Therefore, it is still unknown about the dynamics of CO in the temperate forest ecosystem, especially the response to the micrometeorological and soil environmental change. In this study, we intended to clarify the effects of the differences of the soil environment by measuring soil CO flux with the closed-chamber method and a laser spectrometer.

Soil CO flux was observed in Kiryu hydrological study site (KEW), in Shiga Prefecture, Japan. KEW has 55-year-old cypress forests. Priority species of the forest floor is Eurya japonica growing sparsely. CO fluxes between soil surface and the atmosphere were measured using the closed chambers, in which changes in CO concentration during the chamber closure were monitored in-situ with the laser spectrometer. Three chambers were set up in three locations under different soil environment. Also, the soil moisture content and soil temperature in the three plots were measured.

We found a significant absorption of atmospheric CO by soil surface. Focusing on the differences with the plot, less absorption was found in the plot of less humus layer. More CO absorption was observed when the CO concentration of surrounding area was high.

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Application of three sap flow techniques for Japanese cedar: attempting to estimate the characteristics of sap movement

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Forests cover about 66% of land area of Japan, and Japanese cedar (*Cryptomeria japonica*) occupies 18% of total forested area. Recently, the water balance of a stand of Japanese cedar has been made clear quantitatively by using eddy-covariance method and sap flow technique in Kyushu Island, Japan (Kumagai et al., 2014; Shimizu et al., 2015). Although Japanese cedar is one of the most representative planted species in Japan, few studies have been carried out except in Kyushu Island. The most common technique of sap flow is thermal dissipation method (TDM, Granier, 1985) in Japan. Heat ratio method (HRM, Burgess et al., 2001) and heat field deformation method (HFD, Nadezhdina et al., 2012) have been widely used among foreign countries, and advantages and disadvantages of these techniques were described (e.g., Vandegehuchte and Steppe, 2013). However, HRM and HFD have not been applied for Japanese cedar in Japan. In this study, we applied TDM, HRM and HFD for a tree of Japanese cedar, and carried out preliminary comparison among three techniques. Based on field measurements, we attempted to estimate the sap flow characteristics within the target tree by three techniques.

We conducted measurements in a mature stand of Japanese cedar, whose age is 62, within Tsukuba Experimental Watershed located in southern part of Mt. Tsukuba, Japan. We picked up a tree of Japanese cedar whose height is 24.9 m and diameter at breast height is 40.4 cm, and applied sensors of TDP, HRM and HFD. We used handmade sensors for TDM (e.g., Iida et al., 2013) and sensors for HRM and HFD manufactured by ICT international Pty Ltd (type SFM1 and HFD8, respectively). Japanese cedar has white zone, in which water movement stops, near the sapwood area. We injected acid fuchsin into a stem, and determined colored area as sapwood. The length of TDM sensor was 20 mm, and sap flux density, which is mean value along the sensor length, was computed by the calibration equation by Granier (1985). The width of sapwood was 44 mm, and additional TDM sensor was inserted into the sapwood at the depths from 20 to 40 mm. On the other hand, the length of HRM sensor was 35 mm, and the sap flow movement was detected at the depths of 12.5 and 27.5 mm. For HFD, the sensor length was 96 mm, and the depths of sap flow detecting were 20, 30, 40, 50, 60, 70, 80 and 90 mm.

The sap flux densities measured at the depth from 20 to 40 mm with TDM was larger than that at the depth from 0 to 20 mm. Similar trend was found in the outputs of HRM and HFD. The results of measurements by three techniques show that active sap flow movement occurred up to the depth of 40 mm of sapwood. The diurnal variations in sap flow movement measured by three techniques were almost same, suggesting the applicability of these techniques to evaluate the characteristics of sap flow for a Japanese cedar. However, additional measurements including thermal diffusivity of wood are necessary to obtain sap flux density by HRM and HFD (e.g., Vandegehuchte and Steppe, 2013): in current stage, we have only qualitative comparisons among three techniques. Moreover, to compare the sap flux densities measured by TDM, HRM and HFD, we have to make clear the azimuthal changes in sap flux density within the target tree: three sensors inserted into different part of a stem in this study. We will present the results including these topics.

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Keywords: Thermal dissipation probe, Heat ratio method, Heat field deformation

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Seasonal change in photosynthetic function of cedar and cypress forest estimated by tower-based chlorophyll fluorescence

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Estimating the carbon cycle in terrestrial ecosystem is very important for predicting the climate change in future. Remote sensing observation with vegetation indices (VIs, for ex., Normalized Differential Vegetation Index: NDVI) has contributed greatly to estimate terrestrial carbon budget. Because conventional VIs represent generally the greenness of ecosystem, however, there has been the less accuracy especially for winter time in evergreen forest where the VIs tend to overestimate the photosynthesical activity due to its nearly constant greenness.

Chlorophyll fluorescence is emitted from the chlorophyll a and b to release the excess sun-light energy, and has been used for detecting the photosynthesis stress in numerous ecophysiological studies so far. Recently, the chlorophyll fluorescence has been utilized to represent the gross primary production (GPP), ecosystem photosynthesical activity, by the satellite remote sensing studies (e.g. Frankenberg *et al*., 2011, GRL). However, small number of chlorophyll fluorescence observation on the ecosystem scale at the ground reduces its availability despite its highly expected usefulness.

The aim of this study is to clarify the relationships between chlorophyll fluorescence, and photosynthesis and light use efficiency (LUE) by the ground based measurement in coniferous evergreen forest. The observations were carried out in the plantation forest consisting of mature Japanese cedar and Japanese cypress in Takayama, Japan, from 2007 to 2008. Downward and upward spectral radiances were measured with hemispherical spectroradiometer (MS-700, Eko Instruments, Japan) mounted at 30m-high above the ground surface. We calculated the Sun-Induced fluorescence (F_S) around the O_2-A band from the spectral data with the Fraunhofer Line Depth method. The GPP was calculated from the carbon fluxes measured with eddy covariance at the top of the tower (Nagai *et al*., 2012). Both F_S and GPP were averaged for 30 minutes.

F_S showed the strong correlation to GPP linearly in the diurnal course (sunny day (2007/08/10): r^2 = 0.81, cloudy day (2007/07/24): r^2 = 0.87) and logarithmically in the seasonal change (2008 (half-hour): r^2 = 0.68, 2008 (daily): r^2 = 0.87). The GPP was fitted against the F_S for each month by the following rectangular hyperbolic curve:

$$GPP = \alpha GPP_{SAT} F_S / (GPP_{SAT} + \alpha F_S),$$

where α is the initial slope of the F_S-GPP curve and GPP_{SAT} is the saturated GPP at high F_S emission. These two parameters showed the clear seasonal change. The root-mean-square error (RMSE) calculated for 2008 was 4.56 $\mu molCO_2\ m^{-2}\ s^{-1}$. We also investigated the relationship between F_S and LUE in daily averages. The F_S-LUE relationship could be regressed by logarithm curve for each month (r^2 = 0.46 ˜0.95). The seasonal changes in the regression coefficients for F_S-GPP and F_S-LUE curves were thought to be induced by the seasonal variation in the temperature-dependency of photosynthesis and the phenology.

We conclude that F_S can be utilized to estimate GPP and LUE in evergreen forest, and that relationship between F_S and GPP is influenced by environmental factors such as air temperature.

Keywords: Remote sensing, Light use efficiency, Eddy covariance, Carbon cycle

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Year-to-year variability in the timing of start and end of growing season in deciduous forests in Japan

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Accurate detection of the spatio-temporal variability in the timing start (SGS) and end of growing season (EGS) is important but challenging task to evaluate the ecosystem functioning and service in deciduous forests under meteorological and climate changes. Here, (1) we detected the spatio-temporal variability in the timing of SGS and EGS in Japan from 2001 to 2013 by analysing Terra/Aqua MODIS satellite-observed daily green-red vegetation index (GRVI) with a 500-m spatial resolution; (2) we examined the spatio-temporal variability in the timing of blooming of cherry, leaf-flushing of ginkgo, leaf-colouring of ginkgo and maple, and leaf-fall of ginkgo and maple based on dataset of *in situ* phenological observation; and (3) we evaluate the relationship between year-to-year variability in the timing of satellite-observed SGS and EGS and those of *in situ*-observed SGS and EGS. We found that (1) the year-to-year variability in the timing of SGS, EGS, blooming, leaf-flushing, -colouring, and -fall showed characteristics along vertical and/or horizontal gradients; and (2) the year-to-year variability in the timing of SGS correlated with those of blooming of cherry and leaf-flushing of ginkgo in Hokkaido and Tohoku.

Keywords: satellite data, biometeorological data, deciduous forest, Japan, phenology, year-to-year variability

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Differences in inter-annual variation in flowering and budding dates at two different climatological sites in Japan

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To investigate the relationship between the inter-annual variability of the flowering and budding phenology and their geographical characteristics in Japan, we analysed the first flowering and budding dates of various plant species during winter and spring (Japanese camellia, persimmon, ginkgo, mulberry, narcissus, cherry, Japanese apricot, rhododendron, dandelion, Japanese wisteria, and Japanese lawn grass) from 1953 to 2011 at two different climatological study sites (Takayama, a northern colder site; Gifu, a southern warmer site). We found that (1) fewer than half of the species showed a trend of earlier phenology at both sites, (2) mean phenological dates at Gifu were distributed at wider range (DOY [day of year] 21.9 to 145.2) than those at Takayama (DOY 95.5 to 165.5), and (3) the species with earlier flowering or budding at Gifu showed higher variability and advanced phenology compared with plants that had later flowering and budding. These findings (a) suggest the possibility that flowering and budding phenology in central Japan has a localized response to increasing air temperature and (b) suggest the importance of the long-term and continuous observation of flowering and budding phenology for a range of plant species at multiple sites (Inoue and Nagai, *under review*).

Keywords: phenological observation, flowering date, budding date