iLEAPS-Japan 研究集会 2022

大気－陸面プロセスの研究の進展：観測とモデルによる統合的理解

要旨集*

開催日　：2022 年 12 月 1 日(木)・2 日(金)

場所　　：名古屋大学研究所共同館 II ・409 室　（地球水循環共用室）

　　　　　および、オンライン会場

主催　　：名古屋大学宇宙地球環境研究所・日本学術会議 iLEAPS 小委員会

※(兼)
名古屋大学宇宙地球環境研究所
令和 4 年度共同利用・共同研究（研究集会）
報告書

開催趣旨

iLEAPS（Integrated Land Ecosystem– Atmosphere Process Study：統合陸域生態系―大気プロセス研究計画）は、大気－陸域境界で生じる物理的・化学的・生物学的な諸過程についての理解の促進を目的とした国際研究計画です。iLEAPS は、持続可能な人間社会の構築を目的とした国際的な研究プラットフォームである Future Earth の、GRPs (Global Research Projects) の一つとして位置づけられています。我が国においては、日本学術会議 環境学委員会・地球惑星科学委員会合同 FE・WCRP 合同分科会の下部組織として iLEAPS 小委員会が設けられています。大気－陸域プロセスに関わる研究としては、これまで野外観測、広域モニタリングデータ解析、数値モデル開発が行われ、個葉の環境応答からグローバルな変動まで様々な時間・空間スケールにおける研究が行われてきました。iLEAPS は、このような多岐にわたる手段から得られた様々な知見の統合的理解を目指しています。本研究集会では、大気－陸域プロセスに関心のある研究者にお集まりいただき、各自の最新の研究成果を報告し、その統合的理解に向けた情報共有と議論を行います。特に、観測とモデルによる統合的理解について議論し、大気－陸域プロセスをベースとした気候変動予測研究の推進において、今後何が必要であるかについて議論します。

文責：佐藤永（海洋研究開発 機構・日本学術会議 iLEAPS 小委員会委員長）

iLEAPS-Japan2022 研究集会　プログラム

12 月 1 日（木）

座長：伊勢武史（京都大学）

13:00〜13:05 主催者挨拶と主旨説明（佐藤永・iLEAPS-Japan 小委員会 委員長）

13:05〜13:10 ロジ説明（檜山哲哉・iLEAPS-Japan 小委員会 前委員長）

13:10〜13:35 菊池 千尋（大阪府大）ほか 2 名
Increases in CH_4 uptake associated with rising atmospheric CH_4 concentrations at a temperate forest soil

13:35〜14:00 高橋 けんし（京都大）ほか 7 名
Methane emission from the stem surfaces of Alnus japonica

14:00〜14:25 高村 直也（東大）ほか 5 名
El Niño-Southern Oscillation forcing on carbon and water cycling in a Bornean tropical rainforest

14:25〜14:50 篠塚 賢一（岐阜大）ほか 6 名
Nitrate input to the river from atmospheric deposition observed in Yakushima Island, the world natural heritage site

14:50〜15:15 田代 悠人（名古屋大）ほか 3 名
Possibility of permafrost degradation for the source of the great increase in dissolved iron concentration in the Amur River basin during 1995– 1997

15:15〜15:30 休憩

座長：佐藤永（海洋研究開発機構）

15:30〜15:55 ペク ムンソン（千葉大）ほか 3 名
Generating a new land cover product across Siberia by fusing global land cover datasets

15:55〜16:20 山本 雄平（千葉大）ほか 5 名
Terrestrial vegetation monitoring using Himawari-8 hyper-temporal land surface temperature data

16:20〜16:45 Hantao Li（北海道大）ほか 18 名
Mapping Forest Canopy Height over Japan Using Multisource Remote Sensing Data

16:45〜17:10 Kazuhito Ichii（千葉大）ほか 9 名
Toward hyper-temporal terrestrial monitoring with new generation geostationary satellites

17:10〜17:35 近藤 雅征（名古屋大）
Key uncertainties in the uncertain world of biogeochemistry

17:35〜17:45 第一日目・総括

18:30〜20:30 懇親会（レストラン花の木）

12 月 2 日（金）
座長：近藤 雅征（名古屋大学）

09:00～09:25 中岫茉希（北海道大）ほか 2 名
Projected climate change impacts on wheat production by process-based model MATCRO-Wheat

09:25～09:50 Astrid Yusara（北海道大）ほか 9 名
Development of the process-based soybean growth model (MATCRO-Soybean)

09:50～10:15 佐藤 永（海洋研究開発機構）
Predicting dominant terrestrial biomes at a global scale: Assessments of machine learning algorithms, climate variables indexing, and extreme climate

10:15～10:25 休憩

10:25～10:50 福富 慶樹（名古屋大）ほか 1 名
Characteristics of Synoptic-Scale Waves in the Northern Eurasian Storm Track during Summer

10:50～11:15 伊藤 昭彦（国立環境研）Online 発表
Ammonia volatilization simulated by global biogeochemical models

11:15～11:30 第二日目・総括、閉会の挨拶

11:40～12:30 第 25 期・第 3 回 iLEAPS 小委員会（小委員会メンバーのみ参加・非公開）

※発表は、プレゼンテーション 15 分+質疑応答 10 分

オンサイト会場のご案内

名古屋大学東山キャンパス 宇宙地球環境研究所 研究所共同館 II・409 号室(地球水循環共用室)
https://www.nagoya-u.ac.jp/upload_images/campus_map_jp.pdf ←この地図の右端 F3⑧です

オンライン（Zoom）会場のご案内

2022 年 12 月 1 日（木） 13:00～17:45
https://us02web.zoom.us/j/83773797036?pwd=N2lDMmNQd3NNb28yUExtTG5KOFBwZz09

2022 年 12 月 2 日（金） 09:00～11:55
https://us02web.zoom.us/j/83853765819?pwd=YnVpT0RCQUs5SVhLVG5JSjgvLzdPQT09

パスワードは配信しません。待機室を設けて、実行委員会で入室管理いたします。
オンライン参加される方は、事前に Zoom のインストールをお願いいたします。

Increases in CH_4 uptake associated with rising atmospheric CH_4 concentrations at a temperate forest soil

Chihiro Kikuchi[1*], Masahito Ueyama[2], Satoru Takanashi[3]

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Objectives: CH_4 is a potent greenhouse gas that contributes to global warming, and their atmospheric concentration has risen continuously. Although methanotrophs uptake CH_4 in aerobic soils, no field study has quantified how CH_4 uptake increases with rising atmospheric CH_4 concentrations. In this study, we developed a measurement system for artificially rising atmospheric CH_4 concentrations based on an automated closed chamber system. We quantified the response of CH_4 uptake at a temperate forest soil to rising atmospheric CH_4 concentration in near future.

Materials and methods: The experiment was carried out at the Yamashiro Forest Meteorology Research site in Kyoto. The soil type was immature soil. We measured CH_4 and CO_2 fluxes at four locations in the forest using the automated closed chambers. A system that automatically injected a high concentration of CH_4 gas (CH_4: 9739 ppm) every 6 hours was connected to the chamber. Owing to the injection, CH_4 concentration in the chamber increased approximately 2.3 ppm and 2.5 ppm with different injection volumes. These concentrations represent future CH_4 concentration at 2050 expected by the SSP5-85 scenario. The CH_4 flux was calculated from the linear slope for 45 seconds, 165 seconds after the start of high CH_4 gas injection. The difference between the flux at the time of the injection and the average of the fluxes during the 30 minutes before and after the time of the injection was used to quantify the effect of the increased concentration.

Results and discussion: CH_4 uptake increased 1.1- 9.8 times owing to rising CH_4 concentrations (Fig. 1). Magnitudes of the increased CH_4 uptake were greater under the 2-second injections than the 1-second injections, representing that higher CH_4 uptakes were observed under higher CH_4 concentrations. Owing to a system modification at the end of July, the increased CH_4 concentrations in the chamber were changed: approximately 2100 ppb at 1-second injection and 2200 ppb at 2-second injection until the end of July and to approximately 2300 ppb and 2500 ppb hereafter. Therefore, the increased CH_4 uptake since August was higher than in July, and the difference in uptake between 1-second and 2-second injections was clearer.

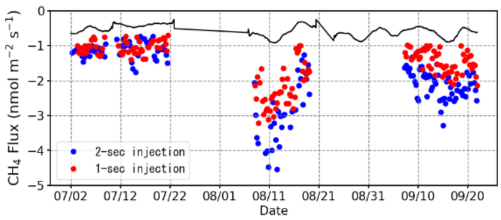

Fig 1. CH_4 fluxes measured by a chamber. The black line represents fluxes without injecting high CH_4 gas, the blue circle represents the flux when injecting the gas for 2 seconds, and the red circle represents the flux when injecting the gas for 1 second.

CH_4 uptake linearly increased with rising CH_4 concentration (Fig 2; R^2 = 0.69). The range of the sensitivity to CH_4 concentrations was 0.0012 to 0.006 nmol m^{-2} s^{-1} $ppb^{-1}$for the four chambers. This suggests that methanotrophs in the soil were stimulated with rising CH_4 concentrations.

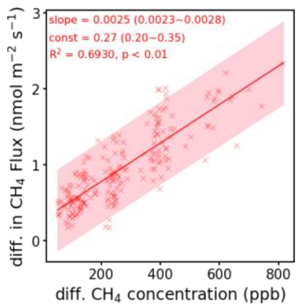

Fig 2. Relationship between increase in CH_4 uptake and rising CH_4 concentrations. The increase in CH_4 uptake is quantified as the difference between the mean flux before and after the injection of the high CH_4 concentration and the flux during injecting high CH_4 gas.

Future works: In this experiment, we could not rule out a potential artifact by diffusion into the soil owing to non-steady conditions of CH_4 concentration profile within the soil. The injection produced a sudden increase in CH_4 concentration, which drove diffusion without sink by methanotrophs. The artifact will be evaluated by solving a non-steady diffusion model. Subtracting the artifact would clarify the sensitivity of biological uptake to rising CH_4 concentrations.

Methane emission from the stem surfaces of *Alnus japonica*

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Atmospheric methane (CH_4) is an important greenhouse gas; therefore, the identification of its source and its quantification are crucial issues in addressing climate change. In recent years, emission of CH_4 from the stems of living and dead trees has drawn considerable attention as a potentially important new source of atmospheric CH_4 (Carmichael et al., 2014; Barba et al., 2019a; Covey and Megonigal, 2019). Findings of experimental studies have increasingly suggested that tree-mediated processes can contribute significantly as a pathway of CH_4 emission in wetland ecosystems (e.g., Terazawa et al., 2007, Pangala et al, 2017). However, the understanding of the mechanisms by which CH_4 is emitted from the stems of living trees remains ambiguous. For example, it is unclear whether trees function as passive "pipes" through which CH_4 is transported diffusively from the rhizosphere to the atmosphere, whether they serve as pipes in which xylem flow transports CH_4 in the dissolved state, or whether living trees produce CH_4 in the heartwood.

The aim of the present study was to elucidate the mechanisms of CH_4 transport inside wetland trees. Our group has been investigating the process by which CH_4 is emitted from the stems of *Alnus japonica* (Thunb.) Steud. trees growing in a riparian wetland with a monsoon climate. In this talk, we report CH_4 emission rates and their seasonal variations based on year-round measurements using a closed-chamber method coupled with near-infrared laser spectrometry for in situ CH_4 detection (Sakabe et al., 2021). The rates of CH_4 emission from the stems of *A. japonica* trees exhibited maxima in summer and minima in winter, and this pattern was closely related to the methanogenic activity in the soil, as demonstrated by path analysis. Furthermore, hourly based measurements conducted throughout the year enabled us to examine the diurnal properties of CH_4 emission rates in detail. We found CH_4 emissions during the leafy season exhibited a diurnally changing component superimposed upon an underlying continuum in which the diurnal variation was in phase with sap flux. We discuss the possible processes giving rise to diurnal variation in the rates of CH_4 emission from the stem surfaces of *A. japonica*, especially in terms of the relation between the CH_4 emission rates and sap flux (Takahashi et al., 2022).

In addition, in order to explore the mechanistic insights into stem CH_4 emissions in the present study, fine root sampled of *A. japonica* were collected and observed using optical and cryo–scanning electron microscopy (cryo-SEM). Previous optical microscopy studies have indicated that the pathway for gas exchange between the roots and aboveground environment is composed of the aerenchyma, a type of tissue comprising a relatively high proportion of spaces or lacunae (Takahashi et al., 2014). In our study, cryo-SEM was also used to elucidate the distributions of water in the observed tissue at a given point in time (Azuma et al., 2016). Using these tools to examine the root tissues of *A. japonica* could help elucidate the mechanisms by which CH_4 is transported in fine roots, either in the gaseous form or dissolved in sap flow. Here, we report the identification of intercellular spaces that could function as conduits for transporting CH_4 molecules in the gaseous state.

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El Niño-Southern Oscillation forcing on carbon and water cycling in a Bornean tropical rainforest

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Inter- and intra-annual variations in the tropical forest canopy CO_2 and H_2O exchanges with the atmosphere through photosynthesis, respiration, and evapotranspiration (ET), might be affected by ordinary seasonal rhythm and sporadic events of tropical climate, influencing total carbon and water cycling in global and regional scales. We assessed the effects of El Niño-Southern Oscillation (ENSO) on net ecosystem CO_2 exchange (NEE) and ET using a 10-year-long eddy-covariance (EC) flux observation, which includes some El Niño (EN) and La Niña (LN) events, and the inverse EC flux model analysis to infer ecophysiological drivers, e.g., canopy stomatal conductance (G_c) and maximum carboxylation rate (V_{cmax25_BL}), in a Bornean tropical rainforest. Analyzing the spectral properties of NEE and ET revealed their strong seasonality, although the study site has the least seasonal variations in precipitation and air temperature worldwide. Also, this implied inter-annual variations in NEE and ET, which ENSO might have induced. The frequency characteristics of the meteorological and ecophysiological drivers correlated to those of NEE and ET. We found that while mean ET over EN, LN, and normal condition (NC) were equivalent, the mean NEE decreased in the order LN > NC > EN. Here, we could explain how G_c, V_{cmax25_BL}, and atmospheric humidity altered the ET and the NEE on each ENSO condition. Further investigation of the mechanisms of the exchanges suggested that solar radiation and V_{cmax25_BL} was the primary controlling factor for ET and NEE, respectively, on LN and NC, but G_c became more significant for both on EN. Further investigation will include Thai tropical evergreen and deciduous forests to find more far-reaching environmental control on Southeast Asian tropical forests canopy exchanges

Nitrate input to the river from atmospheric deposition observed in Yakushima Island, the world natural heritage site

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Introduction: Once nitrate (NO_3^-) emitted to the atmosphere, it may transport everywhere and deposited in terrestrial ecosystem. Several studies have been reported that the increased atmospheric NO_3^- deposition affects the forests and oceans. Yakushima Is. is a mountainous island and located on leeward side of East Asia Continent and is susceptible to the effects of nitrogen oxides from the atmosphere long-range transport. More than 30 rivers flowing down the Yakushima Is. and making it a suitable research site for studying the dynamics of NO_3^- deposition from the atmosphere. The measurement of $\Delta^{17}O_{NO3}$ enables us to reveal the origin of NO_3^- between atmospheres and biological metabolism production. Our object of present research was to determine the proportion of atmospherically produced and biologically reproduced NO_3^- in stream water flowing in Yakushima Is.

Materials and methods: The stream water samples were collected from 21 rivers in Yakushima in December 2018. For the detailed survey, Kawara No.2 stream water samples which is located western area of Yakushima Is. were collected every 100 m elevation from the summit of 1,300 m a.s.l. to the river mouth of 0 m a.s.l. in December 2018, January 2019 and September 2019. These samples were analyzed for dissolved major ion and stable isotope ratios in NO_3^-.

Results and discussions：From the results of the k-mean method using the data set of major ion, Yakushima Is. Rivers were classified into three groups: western forested areas, other rivers and groundwater. The NO_3^- in each class were 20.8, 13.9 and 10.6 μmol L^{-1}, respectively. The river water in the western forested area had higher $\Delta^{17}O_{NO3}$ values than other areas and more NO_3^- of atmospheric origin.

NO_3^- concentration observed in Kawara No.2 stream was 55.0 μmol L^{-1} at 1,000 m a.s.l. elevation and atmospheric origin NO_3^- concentration was also high in winter. Both Cl^- and SO_4^{2-} ions were high at 1,000 m a.s.l., where is prone to fog, suggesting that intense atmospheric deposition is occurring to the island area. With the steep topography of the river, as seen in Kawara No.2 stream, the supply of atmospheric NO_3^- to coastal areas were found to be high.

Possibility of permafrost degradation for the source of the great increase in dissolved iron concentration in the Amur River basin during 1995–1997

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From 1995 to 1997, a great increase in dissolved iron (dFe) concentration was observed in the Amur River and its tributaries. As a reason for this increase, permafrost degradation due to high air temperature in the 1990s was hypothesized. However, the discharge mechanisms of dFe were hardly understood. In order to attack this phenomenon, we studied the interannual variations in annual air temperature (Ta) and net precipitation (precipitation minus evaporation: P − E) in late summer (July, August, and September) from 1960 to 2000 in the Amur River Basin, and then examined the relationship with long-term variation in dFe concentration for the 40 years. Relatively high Ta was found from 1988 to 1990, which was unprecedented continuous warm years. More interestingly, cross correlation analysis showed a significant correlation with a 7-years lag between annual dFe concentration and Ta (r = 0.43–0.55, p<0.01). This 7-years lag correlation was also found between the late summer dFe concentrations and Ta (r = 0.54–0.69, p<0.01). It is also worth noting that correlation between dFe concentration and Ta in the Russian Far East, which is partly underlain permafrost, showed the strongest correlation rather than those in the other subbasins of the Amur River (i.e. Mongolia and China), indicating that increase in dFe concentration in the Amur River is closely associated with warm Ta of 7 years ago in the Russian Far East. Moreover, we found that net precipitation in the Amur River basin increased from 1977 and kept a high value for the next 20 years, which was significantly related to positive PDO (Pacific Decadal Oscillation) from 1977 to 1997. Based on these findings, we provide the following hypothesis for the reason why dFe concentration in the Amur River greatly increased during 1995–1997. (1) Since 1977, wetter soil conditions continued due to increased net precipitation accompanied by positive PDO, which could be favor for microbial dFe generation under an anaerobic condition. (2) Warm years from 1988 to 1990 progressed permafrost degradation, leading to intensive dFe generation in deeper part of the active layer. (3) Generated dFe took approximately 7 years to reach rivers due to low permeability and then caused the great increase in riverine dFe concentration during 1995–1997. Although it is necessary to make this hypothesis more certain, our results emphasize the importance to investigate the climate factors for better understanding the changing arctic river biogeochemistry.

Generating a new land cover product across Siberia by fusing global land cover datasets

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Siberia is one of the regions where temperature increases have been most pronounced in recent years due to climate change. Thus, monitoring of the surface environment is strongly needed. Although land cover is one of the most fundamental variables, large uncertainties still remain. For example, intercomparisons of available land cover products revealed significant discrepancies among them, probably because of sparse validation datasets compared with other regions. Thus, a reliable land cover product for Siberia is required. In this study, we created a new land cover product for Siberia based on the fusions of widely used global land cover products such as Moderate Resolution Imaging Spectroradiometer (MODIS) product, Climate Change Initiative Land Cover (CCI-LC) data, and Copernicus Global Land Service (CGLS)) data. To validate land cover data, we used a multi-source validation dataset (Liu et al., 2019). First, we evaluated available land cover datasets using validation datasets to check accuracy of each land cover product. We identified large variabilities in the accuracy of land cover datasets. Second, we applied three approaches, mode and two fuzzy approaches (e.g. Jung et al. 2006) to integrate existing land cover products. The resulting land cover products were further evaluated using the validation dataset. Finally, the new fusion product of land cover in Siberia is obtained from the best results of the 3 methods. The resulting datasets based on the prototype model using three land cover data show that: (a) the land cover product made by the fuzzy 1 method has the highest overall accuracy (71.85%) in the Siberia region, while ones for the mode method is 70.98% and the fuzzy 2 method is 71.49%; (b) the evaluation of the consistency indicates that the forest, cropland, and snow/ice are satisfactory results, although the classification of sparse vegetation and wetland may not be defined enough due to ambiguous boundaries. The new fusion product obtained in this study provides a targeted reference for terrestrial environmental studies in Siberia, and provides data support for exploring changes in vegetation and carbon cycle.

Terrestrial vegetation monitoring using Himawari-8 hyper-temporal land surface temperature data

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Land surface temperature (LST) is a key parameter of the surface energy, water, and carbon budgets at various scales. The geostationary meteorological satellite Himawari-8 has improved temporal, spatial, and spectral resolutions, enabling high-frequency (10 min) LST estimation in Asia and Oceania regions. We have developed different retrieval algorithms from Himawari-8 data (two nonlinear split-window algorithms and a nonlinear three-band (NTB) algorithm) and validated it using in-situ LST at AsiaFlux and OzFlux sites, and intercomparison with the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station LST. The validation results showed reasonable accuracy (~2.0 K in vegetated surfaces) for all algorithms, with the NTB algorithm having the highest accuracy and the highest robustness to input error. In particular, the NTB algorithm had ~1.0 °C higher accuracy than the other algorithms in regions with extremely high temperature, humidity, and viewing angle (e.g., Australia, Southeast Asia, and northern China). In this presentation, we will introduce the developed Himawari-8 LST product and its applications. High-frequency LST data is expected to have unique applications such as detection of vegetation drying (change in thermal inertia) and estimation of diurnal changes in gross primary production and evapotranspiration.

Mapping Forest Canopy Height over Japan Using Multisource Remote Sensing Data

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Forest is one of the most significant factors in the global carbon budget, storing a grant number of terrestrial carbon in their biomass (Dong, Kaufmann et al. 2003). Accurate forest estimation is crucial to understand the mitigation of the global carbon budget, anthropogenic disturbance to forest degradation and deforestation, and contemporary global land use change. Improved mapping of forest structure provides critical information for such questions(Drake, Dubayah et al. 2002).Especially, the forest canopy height is considered as the most commonly used attribute to measure forest structure(Hunter and Hunter Jr 1999), as it is always used as a predictor for calculation of relative forest criterions such as aboveground biomass (AGB), carbon storage (CS), forest productivity and biodiversity(Lefsky, Cohen et al. 2002, Simard, Pinto et al. 2011, Zhang, Nielsen et al. 2016) Fine resolution mapping of forest canopy height map is crucial to understand terrestrial ecological system. Global Ecosystem Dynamics Investigation (GEDI) mission provides high accurate spaceborne LiDAR data globally to estimate forest structure attributes, while still leaves a high uncertainty on the accuracy disturbance from forest types and topographic factors. To tackle this research gap and obtain high accuracy modeling data for country wide mapping, we collected airborne LiDAR data over Japan with 1273.80 km2 to calibrate GEDI footprints in different forest types including deciduous broadleaf forest, deciduous needleleaf forest, evergreen broadleaf forest and evergreen need leaf forest. The modified GEDI derived forest canopy height is then computed by weighted function to smooth the bias of data and used to be as modeling data for the prober mapping framework. In our study, we mapped the forest canopy height in 25-m spatial resolution using multisource remote sensing data and GEDI L2A data with high accuracy over Japan. The accuracy assessment by airborne LiDAR with root mean scored error (RMSE) of 5.95 m and validated by GEDI data ranges from 3.72 to 5.75 m stratified by 10 Japan's ecozones. Our result explored the mean average forest canopy height in Japan holds 17.07 m ± 4.50 m, and the forest canopy heigh can be affected by several ecological factors. The proposed machine learning based approach for mapping forest canopy height achieve higher accuracy compared with ground reference data with root mean squared error (RMSE) of 5.95 m. By obtaining and using extensive airborne LiDAR over Japan, we explored that the different types of forest show individually relationship with GEDI data. This intersected GEDI footprints are also compared with slope data and beam sensitivity to evaluate the response between topographic and forest density to data accuracy. A novel framework is conducted to select the most accurate subset of GEDI data for utilizing as training data. We used the modified and accurate GEDI data as training data to map forest canopy height over Japan in 25-m spatial resolution. The validated data ranges from 3.72 to 5.75 m depends on ecozones showing a difference in areas. Our country wide forest canopy height products then compared with the ecological data and explored the forest response to ecological factors. The method may be further improved by upgrading spatial resolution and obtaining high quality satellite images. A more extensive airborne LiDAR dataset over Japan is expected to obtain in the near future. The increasing number of ground reference data may provide a more valid analysis for GEDI data in several directions.

Toward hyper-temporal terrestrial monitoring with new generation geostationary satellites

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The new generation of geostationary satellites have suitable wavelength ranges for vegetation monitoring, including the visible and near-infrared regions, and can make observations at high frequencies, such as once every 10 minutes. Therefore, these are expected to play an important role in terrestrial vegetation monitoring. Himawari-8 is the first new-generation geostationary satellite and observes the Asia-Oceania region every 10 minutes. These data sets will enable us to capture diurnal changes in vegetation and to make observations with higher temporal resolution than ever before. Furthermore, the data sets will be useful for monitoring tropical rainforests, which have been extremely difficult to observe by satellite because of their frequent cloud cover.

We initiated a new project, JSPS core-to-core program GEOLAND-NET to establish an international collaboration network. We will establish a unified ultra-high frequency land surface data set every 10 minutes across Asia, Oceania, and the Americas, centered on the state-of-the-art Himawari-8 meteorological satellite, which Japan was the first country in the world to begin operating. In addition to satellite observations, we will conduct joint research covering in-situ observation networks and modeling communities to contribute to the estimation of the greenhouse gas budget of terrestrial ecosystems in Asia, Oceania, Europe, and the United States, and to the future projection and countermeasures against climate change and weather disasters. This project will foster young researchers and their networks that will lead terrestrial environmental monitoring toward carbon neutrality. In this presentation, we introduce the current status of geostationary satellite-based land observation and our new project and its goals.

Key uncertainties in the uncertain world of biogeochemistry

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Owing to the expanding network of atmospheric and field observations, the increasing availability of satellite remote sensing data, and the sophistication of process modeling and data assimilation, biogeochemical studies have rapidly flourished in the past 30 years. Especially between the late 1990s and early 2000s, key findings were made in today's biogeochemical studies, such as the increasing carbon uptake along with the greening in the northern hemisphere, the increasing carbon emissions by land-use and land-cover changes (LULCC), and the periodic outbreak of massive tropical fire emissions. These findings are considered the established facts today, and various follow-up studies have been conducted over the last two decades.

Along with scientific findings in the past decades, new global and regional estimates of vegetation state and associated carbon fluxes have been developed and become available to the science community. However, this development has introduced another level of difficulty in biogeochemistry, as such inconsistent spatiotemporal variability in multiple data. For instance, more than eight independent global products of Leaf Area Index (LAI) are available, but with different global states on greening or browning of vegetation. Similar issues have been identified in LULCC flux, and fire emissions as multiple data on those variables became available.

This presentation is aimed to have a comprehensive discussion about the plausibility of the past findings on vegetation greening, carbon emissions by LULCC and tropical fire, and how the science community should deal with variability or inconsistency among the currently available datasets. Considering the cases of LAI, LULCC flux, and fire emissions, extra caution should be taken when interpreting a global or regional state of LAI and carbon fluxes using a particular individual product.

Projected climate change impacts on wheat production by process-based model MATCRO-Wheat

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Climate change has a significant impact on crop yield and food security at the global scale. High temperature by global warming has negative effects on wheat yield(Gourdji et al., 2013). Temperature rise causes inhabitation of vernalization and damages to grain filling, thus leading to yield reduction(Lobell et al., 2011). On the other hand, high carbon dioxide concentration activates photosynthesis and improves nitrogen efficiency. Elevated CO_2 increased the grain filling rate and final kernel weight, compared to under ambient CO_2(Li et al., 2001). Under the risk that rapid population growth could cause food shortages in near future, therefore, many crop models have been developed to assess future impacts of climate change. For example, the decision Support System for Agrotechnology Transfer (DSSAT) model(Jones et al., 2003) and Agricultural Production Systems Simulator(APSIM) model (Keating et al., 2003) are widely used to simulate effects of climate on crop growth(Asseng et al., 2013). However, such models simplify the physiological processes that affect crop growth and are therefore uncertain for examining the effects of climate change.

This study aims to assess climate change impacts on wheat production in the future and geographically identify key climate variables, by using a crop model, MATCRO-Wheat, recently developed based on MATCRO-Rice model(Masutomi et al., 2016). In MATCRO-Wheat, the detailed biochemical processes of photosynthesis (e.g. Farquhar et al., 1980; Ball et al.,1987) are incorporated so that climate change impacts on wheat production can be understood through the biochemical processes.

MATCRO-Wheat was run at global scale with the spatial resolution of 0.5 degree x 0.5 degree and with the simulation period from 2015 to 2100 to associate this with global temperature and CO_2 changes from preindustrial levels. We examined the relative yield change between 1980-2010('the baseline') and 2071-2100('the future'). Climate data and CO_2 data are derived from ISIMIP(The Inter-Sectoral Impact Model Intercomparison Project). Socioeconomic assumptions (represented by the Shared Socioeconomic Pathway,SSP) are used to cause the uncertainty for the yield growth outlook. In the presentation, the preliminary results on key climate variables will be presented.

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Development of the process-based soybean growth model (MATCRO-Soybean)

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Soybean is one of the world's most important agricultural commodities that provides resources of protein and oil. Most of the soybean products are used for animal feed, and about lower than 25% are for industry and direct human consumption. It is expected that soybean consumption will grow higher in the future. However, climate variability and environmental degradation will lead to agricultural yield loss in some vulnerable areas. Global projections and impact assessments of crop production are needed to prepare for national/regional disasters from the food loss hazard, which will help to minimize the damage to agricultural investments in varied conditions. Hence, an accurate estimation of global soybean production is necessary for terms of providing good data for food supply chains.

Current crop simulation models have been widely used to understand the effect of environmental factors on crop growth and development. This study applied a process-based crop growth model MATCRO (Masutomi et al., 2016) with the present climate data to globally simulate soybean production (MATCRO-Soybean). MATCRO was initially developed for rice crops and allows the crop growth model to simulate different crop parameters that can be easily changed including different specific leaf nitrogen content for soybean as a nitrogen-fixing crop. Soybean and Rice are C3 plants that have a similar photosynthetic process.

This study simulates specific leaf nitrogen on soybean that affects the photosynthesis process to estimate the soybean yields and calibrated parameters with field-scale data with different varieties in Brazil (2013-2014), Japan (2013-2017), China (2014-2016), and the United States (2002-2007). The varieties used were Pioneer 93B15, Ryuhou, Jiuyuehang, BRS 284, Nandou12, and Texuan13 which were classified into different relative maturity groups (3, 4, 5, 6.5, 6.5, and 7 respectively). A variety is classified into a specific relative maturity group based on the length of time from planting to maturity that is determined by photoperiod and temperature in a particular geographic location. Different maturity groups and environmental conditions used in this study are expected to represent model capability in capturing varied phenological conditions.

The objectives of this study are to 1) develop a soybean growth version of MATCRO, 2) validate observational soybean yields, aboveground biomass, and LAI measured at four countries, and 3) represent global soybean production. The developed model is a flexible tool that is coupled with climate models and has the input of climate factors, nitrogen fertilizer, crop calendar, soil texture, and carbon dioxide concentration. The development of this process-based crop growth model for soybean will support further analysis of soybean products and the climate change effect in the future. Hence, it is expected that further analysis regarding the effects of environmental changes (e.g. excessed water, drought, and nitrogen dynamics) on soybean yields can be recognized to provide a comprehensive study of the global soybean yield model.

Predicting dominant terrestrial biomes at a global scale: Assessments of machine learning algorithms, climate variables indexing, and extreme climate

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A biome is a major regional ecological community characterized by distinctive life forms and principal plants. Biome distribution is specifically useful for estimating land potential and raising public awareness about land change. At a global scale, biome distribution is largely determined by climatic conditions, while biome distribution is feedback to climate via biophysical and biochemical ways. Therefore, biome distribution is also important for climate projection.

Modeling biome distribution is a classic biogeographical subject, and many methods have been proposed so far (reviewed by Sato & Ise 2022). In this research area, climate data, such as monthly mean temperature and monthly precipitation, was typically summarized as small numbers of climate indices, such as annual precipitation and coldest month mean temperature, and constructed models driven by these indices.

However, with the availability of machine learning algorithms such as decision trees and random forests in recent years, the restrictions on the amount of data used in model building have been relaxed, and it is no longer essential to summarize environmental data into climatic indices. For example, Hengl *et al.* (2018) used a total of 160 types of environmental variables, such as soil and topography, as well as non-indexed climatic values, such as monthly precipitations and monthly averaged temperatures, in addition to the climate index, to build an empirical model of biome distribution using machine learning algorithms. Besides, increasing the number of variables in models entails costs such as a decrease in model adaptability and an increase in the demands for computational power, so it would also be important to employ only a small number of variables that are selected in a parsimonious way.

On the other hand, from the perspective of plant physiology and ecology, the intensity of incidents such as droughts and low temperatures that occur once every ten years (hereinafter referred to as the extreme climate) is a major factor limiting the biome boundaries. Indeed, Beigaite *et al.* (2022) reported that employing extreme climate indices in the model in addition to the typical (average) climate indices increases the accuracy of the decision tree model.

Here, I compared four machine learning algorithms for accuracy to model relationships between the global biome distributions and climate characteristics. I also assessed the influence of converting monthly precipitation and average air temperature (24 variables) into 16 climatic indices on model accuracy. Finally, the influence of the inclusion of extreme climate indices on modeling accuracy was also assessed.

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Characteristics of Synoptic-Scale Waves in the Northern Eurasian Storm Track during Summer

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Synoptic-scale baroclinic waves have been regarded as a primary rain-bearing system which accompanies development of extratropical cyclones and fronts in the high-latitude continental regions. This study examines the dominant structure and characteristics of synoptic-scale (2−8-day periods) waves over northern Eurasia during the 40 summer seasons (JJA 1979−2018). Main focus is on the dynamical characterization of the synoptic-scale waves that are responsible for the day-to-day weather variability in Siberia. The synoptic-scale wave patterns are isolated by using an extended emphatical orthogonal function (EEOF) analysis and a composite based on global atmospheric reanalysis (JRA-55) and gridded gauge-satellite precipitation product (MSWEPv2.8). The resulting wave patterns are classified into two types from two pairs of EEOF modes of the synoptic-scale variability in the 300-hPa geopotential height anomalies. These two different wave types are defined as polar frontal (PF) type and Arctic frontal (AF) type, respectively. The PF (AF) type is represented by the first (second) EEOF pair. The EEOF-based composite analysis distinguishes between these two types of synoptic-scale waves that have different propagation pathways and background conditions. The PF-type waves initiate in the North Atlantic sector to the west of the British Isles. They propagate eastward across Siberia into the North Pacific, and they produce rain mainly over the climatological Eurasian polar frontal zone along the latitudes of 50°−65°N. They exhibit a strong zonal wave train pattern with zonal wavenumber 7−8 scale and eastward phase speed at about 6 m/s. The AF-type wave train arcs along the climatological Arctic frontal zone. The AF-type waves originate in the vicinity of the Scandinavian Peninsula, and propagate eastward at about 7 m/s with zonal wavenumber 4−5 scale. Their passage brings rain in the latitudes of 60°−80°N around the climatological Arctic frontal zone. The development of the synoptic-scale waves is shown to be reflected by unique background conditions over Northern Eurasia. Lower-tropospheric baroclinicity in the south of Siberia and central Asia favors baroclinic growth of the PF-type waves. The AF-type waves are trapped in the well-organized baroclinic zone along the north coast of the Eurasian continent. The baroclinic zone is coupled with a band of strong positive gradient of potential vorticity, suggesting that this band acts as a waveguide for the AF-type waves.

Ammonia volatilization simulated by global biogeochemical models

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Ammonia (NH_3) is a form of reactive nitrogen and plays an important role in the biogeochemical nitrogen cycle. Volatilization from terrestrial ecosystems is major source of NH_3 to the atmosphere, especially from croplands receiving a plenty of chemical fertilizer and manure. However, our quantification of NH_3 volatilization is still uncertain, because less attention has been paid to the process in comparison with greenhouse gases. In this study, I examined the spatial and temporal variations in the NH_3 volatilization simulated by global terrestrial biogeochemical models.

First, I examined the simulation results by a process-based model, VISIT (Vegetation Integrative SImulator for Trace gases [1]). In the model, NH_3 volatilization rate is estimated as a function of soil temperature, water content, pH, and ammonium content. Global annual NH_3 volatilization in 2010–2019 was estimated as 86.3 Tg NH_3-N yr^{-1}; this is about triple of that in 1901, 28.2 Tg NH_3-N yr^{-1}. The increase of NH_3 volatilization was almost in parallel with the increase of fertilizer input (R^2 = 0.989). Strong emissions occurred in central to northern China, India, western Europe, and central North America, where were occupied by croplands (Fig. 1).

In the Nitrogen Model Intercomparison Project (NMIP [2]), at least five more models estimate NH_3 volatilization: DLEM, ISAM, LPX-Bern, ORCHIDEE, and LM3VN. In the presentation, I would like to show several preliminary results of comparison between the models, in terms of annual flux, seasonal change, spatial distribution, and emission factors.

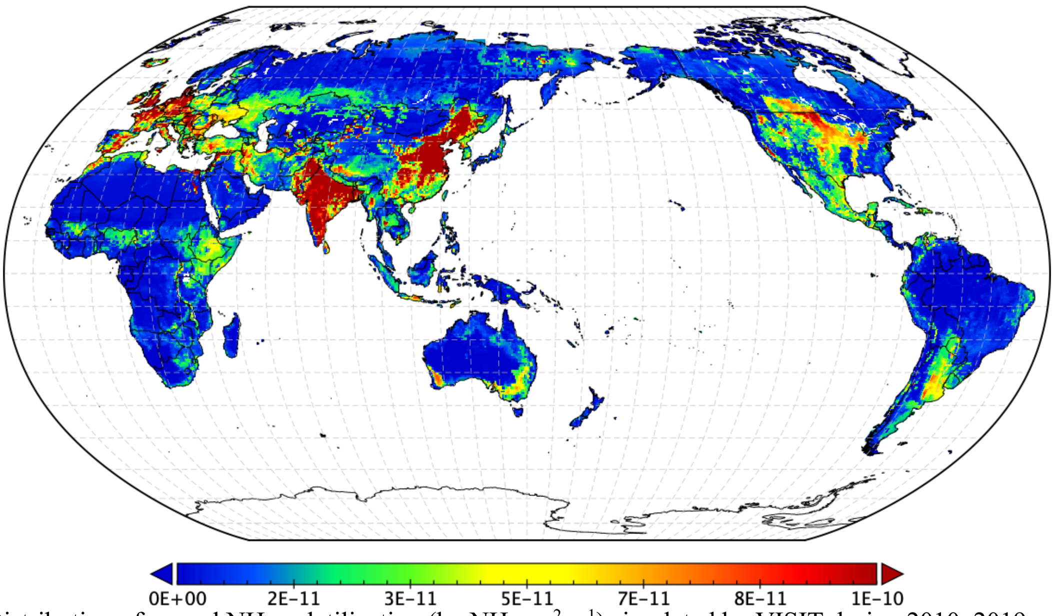

Fig.1 Distribution of annual NH_3 volatilization (kg NH_3 m^{-2} s^{-1}) simulated by VISIT during 2010–2019.

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