Millennium-scale changes in ocean carbon cycle under global warming

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The oceanic uptake of anthropogenic CO_2 from the atmosphere is expected to persist for a thousand years or more. Understanding the oceanic carbon uptake is essential for predicting the air-borne fraction of CO_2 emissions and thus degree of climate change. Warming of ocean surface waters and changes in the ocean circulation and biological pump would reduce the oceanic uptake of CO_2, which is known as climate-carbon cycle feedback.
In this study, we simulate multimillennium changes in ocean carbon cycle under quadrupling of atmospheric CO_2, using GCM (MIROC) and an offline biogeochemical model. We also carry out a number of sensitivity runs in order to isolate the individual feedback mechanisms.
The oceanic uptake is 2050 Pg C, and the reduction of uptake due to global warming is about 30% at the end of simulation. These values are comparable to the previous studies (Plattner et al, 2001; Schmittner et al, 2008). The increase in SST and weaker soft-tissue pump are the dominant mechanisms of climate-carbon cycle feedback. Important biological mechanisms are reduction in new production due to reduced nutrient supply and increase in remineralization rate due to seawater warming.
I will also discuss the effect of ocean circulation change on the oceanic uptake.

Keywords: ocean carbon cycle, multi-millennium simulation, climate-carbon cycle feedback

Global-scale swamp forest modelling using satellite-based elevation and forest datasets

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Swamp forest (seasonally flooded forest) has different characteristics to usual non-flooded forest in terms of carbon pool and nutrient flux. Swamp forest exists in wide climate regions from boreal to tropical regions, but its global distribution is not well studied because satellite observation of inundated forest floor is disturbed by vegetation canopy. Here, we propose a method to estimate the global distribution of swamp forest by global river model simulations using satellite elevation and forest datasets. Digital Elevation Models (DEMs) based on satellite radar or stereoscopy have elevation biases due to forest canopy that impede the simulation of swamp forest hydrodynamics. We removed the elevation biases by combining ICESat forest height data and Landsat forest density data. The simulation with the bias-corrected DEM shows good agreement to L-band radar observation of swamp forest inundation in the Amazon basin, which suggests the potential of the proposed method for estimating swamp forest distribution.

Keywords: Swamp Forest, Global Motel, Flooding

Earth system and climate modeling activities toward CMIP6 in Japan: a review

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There are three groups in Japan planning to contribute to Coupled Model Intercomparison Project (CMIP6): Meteorological Research Institute (MRI) of Japan Meteorological Agency (JMA); Team MIROC, which is a joint effort among JAMSTEC, the University of Tokyo, and NIES; and NICAM development team consisting of UT, RIKEN and JAMSTEC. The first two groups are joining most of the endorsed MIPs with their different model versions combined, while the NICAM team joins CMIP6 in a more selective manner due to the immense computer resource requirement. The third generation of the Earth Simulator, whose theoretical computational speed is 1.3PFlops, will be used for most of the CMIP6 experiments, while the K computer may be utilized for some NICAM experiments. Many activities in Japan for CMIP6 are supported by SOUSEI project funded by MEXT, which is coming to an end in March, 2017. A forum has been set up to involving both scientists and funding agency to discuss overall direction of climate science beyond SOUSEI project.

Keywords: Earth system model, Climate projection, CMIP6

Effect of bias in Leaf Area Index to climate in MIROC-ESM

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Leaf Area Index (LAI) is not only an important factor to determine the amount of photosynthesis, but also a key variable to represent ground surface condition which gives significant impact to atmosphere through biophysical processes such as albedo and transpiration. In this study, we first compared the present-day LAI in Earth System Models (ESMs) with remote sensing data and confirmed the significant overestimation by ESMs, which is pointed out by some existing studies. In order to investigate the effect of the bias, we next compared two pre-industrial control experiments: an ordinary control experiment in which LAI is prognosed by the terrestrial ecosystem component of the ESM, and an experiment in which LAI is replaced with dataset made from remote sensing data (the pre-industrial state was estimated by retuning the cultivated areas to natural vegetation). The result shows a significant temperature difference between the two cases, and by analysis of the related variables we concluded that the difference is caused by albedo change due to the change in snow depth/coverage in May-June and in the sea ice coverage in winter.

Keywords: Leaf Area Index, bias, MIROC-ESM, climate

Socio-economic implications of stabilization scenarios from MIROC-ESM

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Setting a target for stabilization of climate in the long-term requires significant reductions in greenhouse gas (GHG) emissions at global scale. This involves important transformations in the society, basically affecting the future patterns of energy consumption and production, as well as the patterns of land use. Moreover, the cost for achieving such climate target may be considerable, thus, requiring an optimal allocation of efforts that minimizes the economic impact. This study presents the socio-economic implications of emission scenarios aiming at long-term climate stabilization, estimated with an integrated assessment model (IAM). Emission scenarios are obtained from the earth system model (ESM) Model for Interdisciplinary Research on Climate (MIROC-ESM). The outcomes on supply and demand of energy, land use, and mitigation costs are presented.
The emissions scenarios considered are consistent with the representative concentration pathway (RCP), and aim at a global radiative forcing by 2100 of around 4.5 W/m^2 (RCP4.5) and 2.6 W/m^2 (RCP2.6). The Global Change Assessment Model (GCAM) is applied to study the developments in energy, land use and emissions throughout the 21st century. GCAM is an IAM based on a partial equilibrium approach, which resolves the balance in supply and demand across the energy, land use and agricultural sectors.
Compared to the standard RCPs, the emission scenarios from MIROC-ESM presented lower levels of allowable anthropogenic CO_2 emissions for the same climate target. This is an outcome of the stronger feedback between the carbon-cycle and the climate, and the higher value for climate sensitivity assumed in MIROC-ESM in contrast to the climate model used in the development of RCPs. As a consequence, the changes in the energy and land systems are more drastic, while the cost of mitigations is higher. These differences are greater in the second half of the century.

Keywords: MIROC-ESM, stabilization scenario, integrated assessment model

Mineral aerosol as a source of iron for the marine ecosystems in the Southern Ocean

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Atmospheric deposition of dust source materials is a significant source of exogenous iron (Fe) in marine ecosystems. Especially, the Southern Ocean is the most biogeochemically important ocean because of its large spatial extent and its considerable influence on the global carbon cycle. However, there is large uncertainty in our estimate of the dust emissions in the Southern Hemisphere. Here, we implement a newly developed dust emission scheme into a global atmospheric chemistry transport model to produce better agreement with measurements of Fe loading over the oceans.

Keywords: Aerosols , Global Biogeochemical Cycles, Atmospheric chemistry transport model

On constraining the strength of the terrestrial CO_2 fertilization effect in an Earth system model

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Earth system models (ESMs) explicitly simulate the interactions between the physical climate system components and biogeochemical cycles. Physical and biogeochemical aspects of ESMs are routinely compared against their observation-based counterparts to assess model performance and to evaluate how this performance is affected by ongoing model development. Here, we assess the performance of version 4.2 of the Canadian Earth system model against four, land carbon cycle focused, observation-based determinants of the global carbon cycle and the historical global carbon budget over the 1850–2005 period. Our objective is to constrain the strength of the terrestrial CO_2 fertilization effect which is known to be the most uncertain of all carbon cycle feedbacks. The observation-based determinants include (1) globally-averaged atmospheric CO_2 concentration, (2) cumulative atmosphere–land CO_2 flux, (3) atmosphere–land CO_2 flux for the decades of 1960s, 1970s, 1980s, 1990s and 2000s and (4) the amplitude of the globally-averaged annual CO_2 cycle and its increase over the 1980 to 2005 period. The optimal simulation that satisfies constraints imposed by the first three determinants yields a net primary productivity (NPP) increase from ~ 58 Pg C yr^{-1} in 1850 to about ~ 74 Pg C yr^{-1} in 2005; an increase of ~ 27 % over the 1850–2005 period. The simulated loss in the global soil carbon amount due to anthropogenic land use change over the historical period is also broadly consistent with empirical estimates. Yet, it remains possible that these determinants of the global carbon cycle are insufficient to adequately constrain the historical carbon budget, and consequently the strength of terrestrial CO_2 fertilization effect as it is represented in the model, given the large uncertainty associated with LUC emissions over the historical period.

Keywords: Earth system models, CO2 fertilization effect, Land carbon uptake

Multi-model analysis of ocean acidification in the subsurface layers of the North Pacific

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Ocean acidification is one of the major threats for marine calcifying organisms such as precious corals. They live in the mesophotic waters at a depth of 80–300 m near Japan and are known as habitat-forming species with an important structural role in mesophotic habitats of continental slopes, sustaining biodiversity hotspots. Using the outputs of projections under the highest emission scenario of the Representative Concentration Pathways performed by Earth System Models (ESMs), we evaluate the ocean acidification rates in the middle layers of the North Pacific, where the strongest sink of atmospheric CO_2 is found in the mid-latitudes. The mixed layer depth in the Kuroshio Extension region reaches ~200 m during winter due to the strong wind forcing and cooling. Consequently, the low potential vorticity (PV) water mass called the Subtropical Mode Water is formed. This mode water shows large dissolved inorganic carbon (DIC) concentration increase, and is advected southwestward, so that, in the Izu-Ogasawara region, DIC concentration increases and ocean acidification occurs faster than in adjacent regions. The ESMs simulate that pH in the middle layers of the Izu-Ogasawara region decreases by 0.3~0.4 from 2006 through 2100. We find that the ESMs with a deeper mixed layer during winter in the Kuroshio Extension region show the large increase in DIC concentration within the Izu-Ogasawara region. For a reliable projection of the ocean acidification in the middle layers of the Izu-Ogasawara region, an ESM should well reproduce the mixed layer deepening during winter in the Kuroshio Extension region.

Keywords: ocean acidification, CMIP5, Earth System Model

Measurements of Gaseous Nitrous Acid (HONO) Emission from Activated Sludge and Denitrifying Bacteria

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Introduction

Gaseous nitrous acid (HONO) is known as a precursor of OH radicals, a strong oxidant in the atmosphere. Up to 34 % of OH radical is produced from HONO in a city and a rural area[1)]. Therefore HONO is an important species to know OH radical behaviors.
The high HONO concentration have been observed during daytime in spite of the HONO photolysis. There are several known HONO sources: gas phase reactions, heterogeneous reactions and combustion process. Also, HONO emission from soil by the equilibrium between gaseous nitrous acid and aqueous nitrous acid in the soil and the direct emission by nitrifying bacteria have been observed[2)3)]. In the soil, there are not only nitrifying bacteria but denitrifying bacteria. However the emission by denitrifying bacteria is not studied.
The research purpose is to determine whether or not denitrifying bacteria in the activated sludge emits HONO directly.

Experimental

HONO emissions from activated sludge in aerobic condition and anaerobic condition were measured. Also HONO emission from the sterlized supernatant solution was measured. HONO emissions from biological process and chemical process were compared. Activated sludge in Duran bottle was purged with air or N_2 for 1 day to 4 days and HONO was captured with a filter pack. The sludge was aerobic with air purge and anaerobic with N_2 purge. Duran bottle and filter packs were covered with tin foil to avoid HONO photodissociation. Dissolved Oxygen was measured to keep the condition of activated sludge and pH was stabilized at 7.8-8.1 by adding 0.1 M HCl solution or 50 g/L $NaHCO_3$ solution not to decrease the bacteria's activity. The flow speed was controlled at 2 L/min with mass flow controllers.
Also, activated sludge and its sterilized supernatant solution were purged with room air and N_2 at 22 ℃. Also the activated sludge was purged with N_2 at 27, 32 ℃. The activated sludge in a Duran bottle was put in the water which is controlled with a heat controller to stabilize the temperature of activated sludge. In these experiments, three filter packs were placed for each experiment. Air or N_2 was purged in 4.5 L/min because three filter packs were prepared and the purged gas was controlled to flow through each filter pack in 1.5 L/min. The NO_2^- concentrations of the sludge and supernatant were measured before these experiments with the pack test. The purging time was 8 hours in order to keep controlling pH.

Results and Discussion

In this experiment, HONO emissions from the sludge were observed at anaerobic condition. The contribution of biological process was more than 90%. However, calculated activation energy from temperature dependent experiment was much bigger than that of the denitrifying bacteria. Thus, there is a possibiliy that denitrifying bacteria reduce NO_3^- to NO_2^- and the increase in NO_2^- concentration increased the HONO emission from the chemical process. Also, NO_2^- concentration in the sludge should be measured more accurately because it has influence on HONO emission.

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Keywords: nitrous acid, atmosphere, soil

IMPACT OF BIOGEOPHYSICAL AND BIOGEOCHEMICAL PROCESSES AND THEIR INTERACTIONS ON PERMAFROST SOIL CARBON STOCKS

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One of the major challenges in more detailed Earth system models (ESMs) is the treatment of the biophysical and biogeochemical processes and feedbacks and their impact on soil organic carbon (SOC), in the Northern high latitudes (NHL) permafrost region. . This is because a larger suite of active terrestrial processes coupled with scarcity of observational data introduce many challenges for modelling these processes. Nonetheless, several studies in the recent past have demonstrated improved permafrost modelling capabilities by incorporating soil/snow processes that critically influence the ground energetics in these environments, such as: deep soil layers and organic soils, and the effects of wind compaction and depth hoar formations, and structural properties of vegetation (phenology, assimilated vegetation C allocation to leaves, stems, and roots and root dynamics) However, no study has yet evaluated the combined effects of the improvements of these biogeophysical and biogeochemical processes for the entire NHL.

We use a land surface model, the Integrated Science Assessment Model (ISAM), to investigate the effects of feedbacks between the biogeochemical (C and N) and biogeophysical (water, and energy) processes on the model estimated soil organic carbon (SOC) for the NHL permafrost region. We not only focus on recent model improvements in the biogeophysical processes that are deemed important for the high latitude soils/snow and ppermafroest SOC; such as deep soil column, modulation of soil thermal and hydrological properties, wind compaction of snow, and depth hoar formation; but also biogeochemical processes that are important for soil biogeochemistry; such as dynamic phenology and root distribution, litter carbon decomposition rates and nitrogen amount remaining. We select multiple sites to evaluate the modeled processes. We then carried out several model simulations to study the effects of feedbacks between biogeochemical and biogeophysical processes on SOC in NHL.

After accounting for dynamic biogeochemical processes, ISAM is able to capture permafrost extend and and the carbon stored in NHLs, as well as the seasonal variability in leaf area index (LAI), and root distribution in the soil layers and the root response of soil water uptake and transpiration. The evaluation of the model results suggest that without accounting these processes, modelled growing season length (GSL) for NHL was almost two times higher as compared to measurements. To quantify the implication of these processes on the carbon and water fluxes, we compared the results of two different versions of ISAM, dynamic version which accounts for dynamic processes ($ISAM_{DYN}$) and static version which do not account for dynamic processes ($ISAM_{BC}$), with measurements from12 eddy covariance flux sites. The results show that $ISAM_{DYN}$, unlike $ISAM_{BC}$, is better able to capture the seasonal variability in GPP and energy fluxes. Our modelling analysis shows that by including the biophysical processes in addition to biogeochemical processes, the modelled NHL permafrost carbon increased by 30% from 328 to 447 GtC in the top one meter of soil which is in better agreement with observational estimates of 495 GtC (Northern Circumpolar Soil Carbon Database). Even though the inclusion of these processes generally reduced vegetation productivity and litter production due to a decrease in soil temperature and liquid water content, increased soil carbon stocks highlight the dominance of soil water/temperature stress on decomposition processes. While continued improvements are required in the treatment of biogeochemistry, here we demonstrate the importance of soil/snow biogeophysical and biogeochemical

processes in modelling permafrost carbon stocks, as important drivers of soil biogeochemical processes.

Keywords: Permafrost Soil Carbon, Land Surface Model, Biogeophysics, Biogeochemistry

