Global carbon observations by GOSAT series

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Greenhouse gases Observing SATellite (GOSAT) has been monitoring atmospheric column carbon dioxide (XCO_2) and methane (XCH_4) concentrations from space since its launch in January 2009. The primary goal of GOSAT project is to successfully estimate global carbon budget on subcontinental scales using spatiotemporal distribution of XCO_2 and XCH_4. GOSAT observations have provided the basis for assessments of the values of space-based measurements of CO_2 and CH_4 concentrations. This work summarizes the benefit of GOSAT observations for the study of global carbon cycle based on previous studies using GOSAT data, together with limitations in data coverage and density. Then we discuss scientific issues that should be addressed in future missions of greenhouse gases satellites observations.

Keywords: satellite observations, carbon cycle, greenhouse gases

Vertical profile retrieval of greenhouse gases from GOSAT TANSO-FTS SWIR and TIR spectra

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TANSO-FTS onboard GOSAT is the only sensor that measures Short Wavelength InfraRed (SWIR) and Thermal InfraRed (TIR) spectra at the same time and footprint, providing a unique opportunity to retrieve atmospheric CO_2 and CH_4 concentrations from space. Since the launch of GOSAT in January 2009, TANSO-FTS continues to observe greenhouses gases. Nevertheless, the simultaneous use of SWIR and TIR to extract more information on the greenhouse gas concentrations is limited to theoretical studies (e.g., Herbin et al. 2013).

We have developed a greenhouse gas retrieval algorithm which uses SWIR and TIR simultaneously by adding a TIR module to the existing SWIR algorithm of Kikuchi et al. (2016). The algorithm is now evaluated by analyzing GOSAT measurements over Railroad Valley Playa in Nevada during the vicarious calibration campaigns in 2009-2015 for which various validation data are available including the Alpha Jet Atmospheric eXperiment (AJAX) measurements.

Currently, the gas concentrations are retrieved using a small number of vertical layers (2 layers for CO_2 and 4 layers for CH_4) to reduce the influence of a priori, forward model errors and/or possible L1B spectral biases. An example of the retrieved CO_2 profile is shown in Figure 1 together with the a priori profile (a flat profile of 380 ppm) and the AJAX measurement. Figures 2 and 3 show water vapor and temperature profiles, respectively. Also shown in these Figures are the a priori profiles taken from NCEP and in situ measurements by radiosonde. These results demonstrate a synergy effect of SWIR and TIR in retrieving greenhouse gas concentrations.

Keywords: greenhouse gases, GOSAT, remote sensing

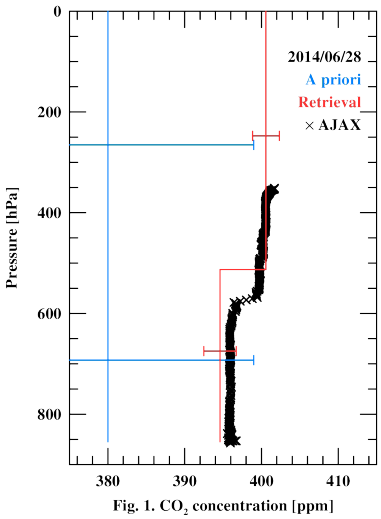

Fig. 1. CO_2 concentration [ppm]

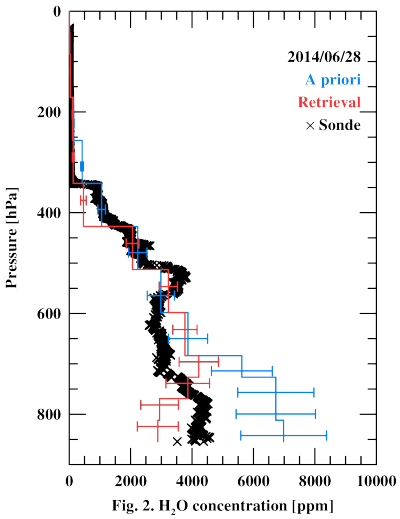

Fig. 2. H_2O concentration [ppm]

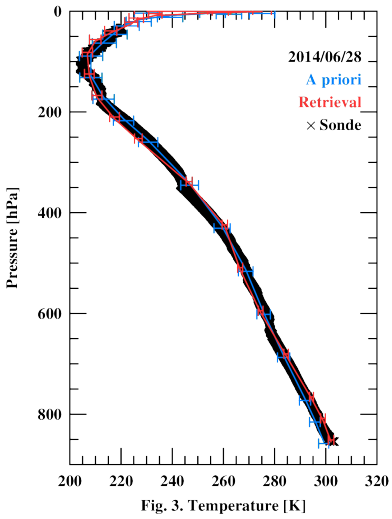

Fig. 3. Temperature [K]

Validation of BESD-SCIAMACHY and SWIR-GOSAT satellite data of XCO2 using TCCON data

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So far, long-term datasets of greenhouse gases have been obtained by multiple satellite observations. However, data acquired with different satellite sensors may have a difference in both spatial and time resolution as well as in its data quality. In this research, we validated two different satellite observation data of XCO2 by using the same ground observation data of Total Carbon Column Observing Network (TCCON). Here, the missing values in the satellite observations was interpolated by multi-B spline interpolation method.
One dataset used in this study was the level 2 data of XCO2 from March 2003 to March 2012, which was acquired based on the monthly Bremen Optimal Estimation DOAS (BESD) algorithm by the Scanning Imaging Absorption spectrometer for Atmospheric Chartography (SCIAMACHY) sensor, a spectrometer for atmospheric measurement of the ENVISAT (Environmental Satellite) satellite by the European Space Agency (ESA). The other dataset was the level 2 of XCO 2 from April 2009 to February 2016 acquired by the FTS / Short Wave Infrared (SWIR) sensor of the Greenhouse gases Observing Satellite (GOSAT) satellite by Japan Aerospace Exploration Agency (JAXA). The validation data was the ground observations at 27 sites of TCCON.
As a result, we found that the ground observation data of TCCON has a good consistency with XCO2 trends observed by both SCIAMACHY and GOSAT. The comparison result at 16 sites showed that the average value of the correlation coefficient (R^2) between TCCON data and SCIAMACHY data was 0.71. On the other hand, the comparison result at 27 sites showed that the average value of R^2 between TCCON data and GOSAT data was 0.74. From these results, we come to a conclusion that the XCO2 data observed by the two satellites showed a good correlation with the ground observations of TCCON. Additionally, we found that the annual fluctuation of the XCO2 concentration at each site has a remarkable increase trend, namely, the annual increase of the XCO2 concentration was between 1.479 and 2.045 (ppm / yr.), and the mean value of the annual increase at 27 observation sites of TCCON was 1.888 (ppm / yr.).
This study is supported by the project “Development of Innovative Adaptation System and MRV Method for JCM in Mongolia" (2015-present) funded by Ministry of the Environment, Government of Japan.

Keywords: SCIAMACHY, GOSAT, XCO2, TCCON

Summary of Global Greenhouse Gas Inventory Databases

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Greenhouse gas (GHG) inventory is a national inventory made to represent the annual GHG emissions or removals by sources. The main purpose of that is helping human to make plans on GHG mitigation so as to control the future national GHG concentrations in the atmosphere at a level that would not destroy the current climate system. After the 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines for national GHG inventories, 2006 IPCC guidelines for national GHG inventories was published. However, many versions of national GHG inventory databases in the world have come out recently. In this paper, the national GHG inventory databases made by Carbon Dioxide Information Analysis Center (CDIAC), Emissions Database for Global Atmospheric Research (EDGAR), Energy Information Administration (EIA), International Energy Agency (IEA), Global Carbon Budget (GCB) and United Nations Framework Convention on Climate Change (UNFCCC) are characterized and compared. The analysis between them is also conducted on distinct and the usability aspects. According to the analysis results, the usability of these versions could be ranked as, EDGAR, CDIAC, IEA, UNFCCC, GCB and EIA. Finally, some suggestions are provided.

Keywords: GHG inventory, Carbon dioxide emissions, Energy concumption, Global warming, IPCC

Monitoring Carbon Cycle Change using an Integrated Observation, Modeling and Analysis System - Project summary

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We conducted a three-year research project to develop an integrated carbon observation and analysis system based on satellite, airborne and ground-based observations, and atmospheric and terrestrial carbon cycle models. Aircraft observations of atmospheric greenhouse gases (GHGs) were strengthened based on the “Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL)” project. Atmospheric transport modeling, inverse modeling, and assimilation methods have also been developed and improved for better utilization of observational data from the Asia-Pacific region. Global and regional surface fluxes were estimated by both "top-down” approach using inverse models and "bottom-up” approach using surface flux observation network data and upscaling with either empirical models or terrestrial ecosystem models.

The main progress over the past three years (FY 2014-2016) have been the better constraints of global, continental and regional carbon budgets, and detection of terrestrial carbon cycle change particularly in the Asia-Pacific region.
1) Multiple approaches including different types of top-down models and bottom-up upscaling techniques contributed to designate uncertainties in the estimates of large emissions (e.g. fuel use and land use changes).
2) Key target regions and events were indicated as potential hot-spots in the Asia-Pacific where we need further targeted research. (e.g. potential increase in terrestrial carbon sink in Siberia and East Asia, uncertainty in the recent rapid growth of anthropogenic GHG emissions in East Asia, emissions from land use change and El Niño-induced extreme forest fires in Southeast Asia)
3) A prototype system was developed and tested for future operational monitoring of changes in regional, continental, and global GHGs budgets based on integration of observation and modeling.
4) Scientific knowledge transfer and educational outreach were provided through domestic and international society activities, training seminars, lectures, and publications.

We also discuss remaining issues and the way to solve them in the next steps (e.g. strategies of intensive observations in targeted area, and a platform for multi-model ensemble)

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Keywords: Monitoring Carbon Cycle Change, Integrated Observation, Modeling and Analysis

Forest photosynthesis from leaf to region, and from present to future: long-term and multidisciplinary research in Japan.

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Carbon cycle and budget, tree water use and hydrological cycle, and primary production are among the major forest ecosystem functions, and there is no doubt that they play key roles in the Earth system and biodiversity. Recent global needs to these themes involves to link such observations with regional and global climate observations in order to find and predict their interactive changes which influence societal security. Promoting our collaborative long-term observations and in-situ experiments would be useful to identify the major observational parameters, methodology and data analysis for our understandings and prediction of environmental changes in regional scale. The GEO Carbon and GHG initiative, as part of the GEO 2017-2019 Work Programme, aims at providing integration across different parts of the system, intends to facilitate the cooperation among existing initiatives/networks/programmes, and promotes the interoperability of data, to fill in the missing pieces to obtain a comprehensive, globally coordinated, carbon and GHGs observation and analysis system. In this poster, a case study at a “super-site” of a forest ecosystem in central Japan will be introduced to address one of the tasks of this GEO Carbon and GHG initiative dealing with the optimization of observational networks. Sharing the data, knowledge and experience gained in this super-site would help seeking essential carbon cycle variables and hence to develop an improved observation design which promotes interdisciplinary and linked observations of in-situ and satellite methodologies.

Long-term observation of CO2 flux at a cool-temperate deciduous broadleaf forest named “Takayama site”, located in a mountainous landscape in central Japan (TKY site) revealed that net ecosystem production (NEP) shows remarkable seasonal change from spring to summer, and to autumn, with different magnitude of the maximum NEP in summer over multiple years. In order to clarify its plant ecophysiological mechanisms we monitored phenology of single leaf level photosynthesis and canopy leaf area index for several years. Our cross-scale observations and model analysis showed that inter-annual variations in leaf expansion and senescence in spring and autumn, respectively, as well as the inter-annual variation of weather in summer affected activity of forest canopy photosynthesis (Gross Primary Production: GPP). Open-field warming experiments on canopy tree foliage suggested that warmer spring and autumn induce earlier leaf expansion and delayed leaf senescence, and 10% higher photosynthetic capacity of leaves. Model simulation also suggested about 20% increase of NEP in this forest in late 21st century.

Keywords: Carbon cycle, Photosynthesis, Phenology, Observation network

Characterizing and Quantifying Fog Interception, Energy Distribution and Flux Patterns in a Subtropical Montane Cloud Forest Ecosystem

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The montane cloud forest ecosystem is known to be very productive in the global scale even though its spatial distributions is in very limited regions in the mountain area of tropical and subtropical regions. However, the amount of cloud-water interception by the cloud forest canopy structure remains a big issue for researchers to quantify the physical and ecological environment in such ecosystem. In this study, in order to quantify how the occurrence and formation of upslope cloud/fog affect the cloud-water interception, radiative vertical profiles, and flux patterns inside the canopy volume of the subtropical montane cloud forest, A series of filed experiments and mathematical analysis is being conducted in Chi-Lan Mountain Flux Site in northeastern Taiwan. There are three major research objectives to accomplished in this proposed project on a three-year basis. First, this study is trying to quantify the amount of cloud-water interception collected by the canopy volume, and establish the relationship between the cloud-water interception and the environmental factors (temperature, humidity and wind components). Second, this study analyzes the allocation and dynamics of radiative components (direct beam and diffuse radiation) throughout the canopy volume under the influences of upslope cloud/fog. Finally, this study applies the Eulerian CSO methods to quantify the scalar exchanges and flux patterns in the cloud forest ecosystem under neutral and stable atmospheric stability conditions

Keywords: cloud-water interception, upslope fog, inverse model, diffuse radiation

A sharp increase in CO2 concentration in West Siberia: anthropogenic impact or response of Siberian ecosystems to a changing climate

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A sharp increase in CO2 concentration in West Siberia: anthropogenic impact or response of Siberian ecosystems to a changing climate

Long-term airborne observations of greenhouse gases carried out in the troposphere over south-western area of West Siberia since 1997 allowed some specific features in CO_2 trends to be revealed at different heights. At an altitude of 7 km above ground level (AGL), the average annual rate of CO_2 increase was 1.72 ppm yr^{-1}. The main distinctive features in the tendencies of CO_2 mixing ratio have been found in the lower troposphere. Thus, for the period from 1997 to 2004, July concentrations of CO_2 at an altitude of 500 m AGL increased slightly with a rate of 0.17 ppm yr^{-1}, while since 2005 they began to rise dramatically with a rate of 3.64 ppm yr^{-1}.

Analysis of the possible causes of such long-term behavior showed that it was resulted from neither reduction of forest area, nor wildfires, nor forest diseases. Also it is impossible to state that reducing CO_2 sink has been caused by the impact of climate changes on ecosystems.

Possibly, anthropogenic CO_2 accumulation resulted in that Siberian forests cannot assimilate such additional amount of carbon dioxide. A decrease in the sink for atmospheric CO_2 is also observed in the Amazon (Brienen et al. 2015). Brienen et al. (2015) assume that it may be caused by a sustained long-term increase in tree mortality. There is also a supposition that it can be a result of a vegetation replacement by other types of plants or young trees, which absorb less amount of CO_2 (Kunstler et al., 2015; Crowther T. W., 2015). However, it seems highly unlikely to test these hyposeses in the near future due to a huge area of West Siberia, most regions of which are difficult to access.

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Keywords: Atmosphere, Concentration, Greenhouse gases, Tendencie

