Global carbon modeling using GOSAT observations

*Makoto Saito[1], Yukio Yoshida[1], Hibiki Noda[1], Isamu Morino[1], Osamu Uchino[1], Tsuneo Matsunaga[1], Tatsuya Yokota[1], Shamil Maksyutov[1]

1.National Institute for Environmental Studies

The Greenhouse gases Observing SATellite (GOSAT) was launched on January 2009 to measure spatiotemporal variations of column carbon dioxide (CO2) and methane (CH4) concentrations from space. The GOSAT measurements provide uniform global coverage and thus show a standardized distribution and CO2 and CH4 concentrations over the globe, allowing an assessment of potential impact of climate change on the CO2 and CH4 budgets. Here we show how drought events influence CH4 emission in the Amazon region by using the GOSAT observation, as a case study to examine utilizationof of earth explore satellites for advancing our understanding of the global carbon cycle and for distinguishing emission sources from the atmospheric concentrations.The GOSAT mission can be considered as a demonstrator for discussing future missions of greenhouse gas observing satellites.

Keywords: satellite observations, global carbon budget, greenhouse gases

Current Status of GOSAT and GOSAT-2 Projects

*Ryoichi Imasu[1], Tatsuya Yokota[2], Tsuneo Matsunaga[2], Masakatsu Nakajima[3], Yukio Yoshida[2], Naoko Saitoh[4], Gen Inoue

1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.National Institute for Environmental Studie, 3.Japan Aerospace eXploration Agency, 4.Center of Environmental Remote Sensing

GOSAT (Greenhouse gases Observing Satellite) is the world's first satellite dedicated to greenhouse gas monitoring from space, and it was successfully launched on January 23, 2009. Although it has finished its nominal operation period (5 years) in January 2014 and is currently in the extended operation period, it has still been monitoring the Earth's atmosphere continuously. The data have been widely used not only for source/sink inversion of carbon dioxide and methane in global scale but also for assessing regional emission sources of the gases. The successor, GOSAT-2, will be launched in FY2017. Most of the design reviews for spacecraft, instruments, and ground data processing systems have been finished. The main sensor of GOSAT-2, Thermal And Near- infrared Sensor for carbon Observation -Fourier Transform Spectrometer (TANSO-FTS)-2 is designed based on CrIS (Cross-track Infrared Sounder) onboard NASA's Suomi NPP for gas sounding. It has a widened band in a short wavelength infrared region to detect carbon monoxide (CO). Intelligent pointing system, which is a dynamical system for targeting at selected clear sky scenes has been newly developed. It is expected that the detectability of clear sky scenes become larger twice or more compared with the current system. "GOSAT Air Pollution Watch" is being designed for rapid processing / distribution of GOSAT TANSO-Cloud and Aerosol Imager (TANSO-CAI) data for monitoring of air pollution caused mainly by particulate matters such as PM2.5 and Black Carbon (BC). Its testbed is already developed and basic performances have been demonstrated using TANSO-CAI data. Data processing algorithms in GOSAT Air Pollution Watch are based on but modified from GOSAT/GOSAT-2 algorithms for aerosol product so as to realize faster and timely data processing. Its data will be used to inform the current distribution of the polluted air. In addition, they will contribute to short term prediction of air pollution using atmospheric transport models. NIES would like to issue "Call for new GOSAT Air Pollution Watch partners" to extend the coverage of the testbed to Southeastern and South Asian countries. These activities may have close relationships to JCM (Joint Crediting Mechanism) activities between Japan and Asian countries.

Keywords: GOSAT, Carbon dioxide, Methane, GOSAT Air Pollution Watch

Measuring Atmospheric Carbon Dioxide with the NASA Orbiting Carbon Observatory-2 (OCO-2)

*David Crisp[1]

1.Jet Propulsion Laboratory, California Institute of Technology

The NASA Orbiting Carbon Observatory-2 (OCO-2) was successfully launched from Vandenberg Air Force Base in California on 2 July 2014. Two months later, its spectrometers began routinely returning almost one million soundings over the sunlit hemisphere each day. About 10% of these soundings are sufficiently cloud free to yield full-column estimates of the column-averaged CO_2 dry air mole fraction, X_{CO2}. Nadir soundings over land yield X_{CO2} estimates with single-sounding random errors that increase from 0.5 ppm to 1 ppm between the sub-solar latitude and solar zenith angles near 60 degrees. Observations of the glint spot over the ocean yield X_{CO2} estimates with single sounding random errors near 0.5 ppm at solar zenith angles below 70 degrees. The initial observing strategy recorded only glint or nadir observations over the entire sunlit hemisphere for a complete, 16-day, ground-track repeat cycle, and then used the other observing mode in the next 16-day cycle. This approach provided adequate coverage of oceans and continents on monthly time scales, but produced 16-day long gaps in the coverage of the ocean while in nadir mode, and limited coverage of high latitude continents while in glint mode. In early July of 2015, this observation strategy was modified to alternate between glint and nadir observations on alternate orbits to yield more continuous coverage of the entire sunlit hemisphere every day.
Preliminary, global maps of X_{CO2} compiled from soundings collected over 16-day ground track repeat cycles reveal some of the most robust features of the annual atmospheric carbon cycle. Regions of enhanced X_{CO2} that are co-located with intense fossil fuel emission sources in the eastern US and eastern China were most obvious in the fall and early winter of 2014, when the north-south gradient in X_{CO2} was small. X_{CO2} enhancements coincident with intense biomass burning in the Amazon, central Africa, and the Indonesian Archipelago were also most obvious during this season. In the early spring, when the pole-to-pole gradients in X_{CO2} are largest, contributions from these emission sources were clearly seen in individual orbit tracks but were much less obvious in the global maps. However, between late May and early July of 2015, OCO-2 maps show a 2-3% reduction in X_{CO2} across much of the northern hemisphere, as the land biosphere rapidly absorbs CO_2 through photosynthesis. As the carbon cycle science community continues to analyze these OCO-2 data, quantitative estimates of regional-scale emission sources and natural sinks (absorbers) are expected to emerge.
The OCO-2 team started delivering Version 7 products to the Goddard Earth Sciences Data and Information Services Center (GES-DISC) in early June 2015. These products include calibrated, spectral radiances (Level 1 products), and retrieved geophysical quantities, including spatially resolved estimates of XCO2, surface pressure, and solar-induced chlorophyll fluorescence (Level 2 products). The calibration of the Level 1 products continues to be refined, and the effort to cross calibrate these products with those from the Japanese Greenhouse gases Observing SATellite (GOSAT) are under way. The Level 2 products are currently being validated against observations from the Total Carbon Column Observing Network (TCCON) and other standards to identify and correct biases. This presentation will summarize these and other aspects of the OCO-2 mission status, early products, and near-term plans.

Keywords: carbon dioxide, carbon cycle, remote sensing

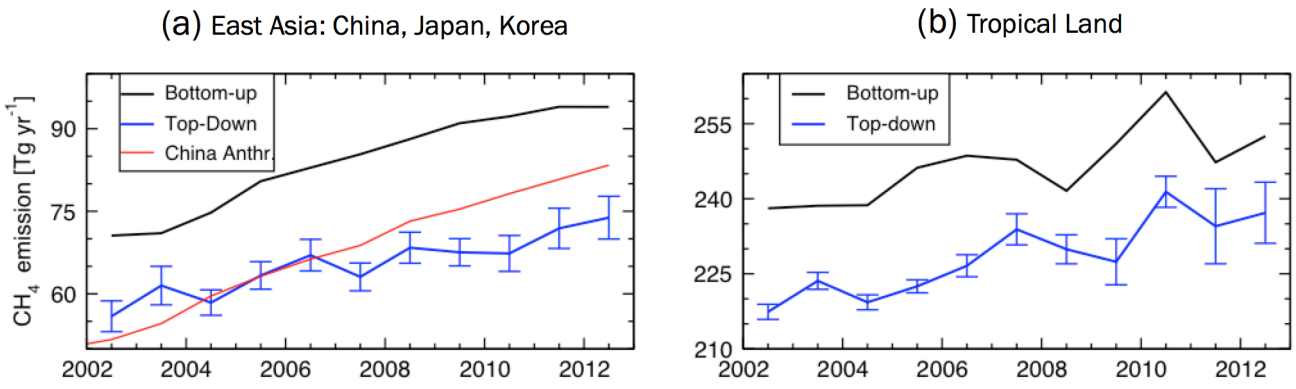
Regional methane emission estimation based on observed atmospheric concentrations (2002–2012)

*Prabir Patra[1,2], Tazu Saeki[1], Edward J Dlugokencky[4], Kentaro Ishijima[1], Taku Umezawa[3], Akihiko Ito[3], Shuji Aoki[2], Shinji Morimoto[2], Eric A Kort[5], Andrew Crotwell[4], Ravi Kumar Kunchala[6], Takakiyo Nakazawa[2]

1.Department of Environmental Geochemical Cycle Research, JAMSTEC, Yokohama, Japan, 2.CAOS, Graduate School of Science, Tohoku University, Sendai, Japan, 3.National Institute for Environmental Studies, Tsukuba, Japan, 4.NOAA Earth System Research Laboratory, Colorado, USA, 5.University of Michigan, Michigan, USA, 6.Arctic GRENE, National Institute of Polar Research, Tachikawa, Japan

Methane (CH_4) is one of the most important short-lived climate forcers (SLCFs) due to its dual roles as a strong greenhouse gas and in air pollution chemistry. A better understanding of the regional (country-level) emissions is required for effective policymaking for emission mitigation as well as for evaluating progress of the committed INDCs (Intended Nationally Determined Contribution) at the Conference of the Parties (COP21) in Paris in 2015. An atmospheric chemistry-transport model (i.e., JAMSTEC's ACTM) has been developed to simulate greenhouse gases and ozone depleting substances. With atmospheric CH_4 lifetime being ~10 years, accurate knowledge of the transport and chemistry are established first for monitoring and verification of CH_4 emissions using atmospheric data by inverse modeling (referred to as top-down method). We have performed an ensemble of 7 inversions, by varying the bottom-up emissions for top-down estimation of CH_4 emissions from 53 partitions of global land using the ACTM forward simulations and atmospheric measurements at 39 surface sites. Our top-down results show that CH_4 emissions for the East Asian and Tropical regions are overestimated, up to about 20 Tg/yr (1Tg = 10^{12}g) each, by the bottom-up method. In contrast, top-down estimation for the southern extratropics is about 10 Tg/yr higher CH_4 emissions compared to the bottom-up method. Furthermore, the emission increase between 2002 and 2012 is also overestimated by the bottom-up method for East Asia. We use additional observational evidences to show that CH_4 emissions from coal burning is overestimated from the East Asia (China) region, and the emissions from enteric fermentation (livestock farming) is increasing in the tropical countries. We determine the tropical CH_4 emissions increase is due to livestock farming, based on an analysis of observed carbon isotopes of CH_4 ($\delta^{13}C$) by Tohoku University and animal population from Food and agriculture organization (FAO) statistics.
This study has been carried out as part of Grant-in-Aid for Scientific Research (A) (Research Number: 22241008), Suishin-hi (Research Number: 2-1401), and the Japan Society for the Promotion of Science and Arctic Climate Change Research, Green Network of Excellence (GRENE) Project (led by National Institute of Polar Research) by Ministry of Education, Culture, Sports, Science and Technology.

Keywords: greenhouse gases, source/sink inversion, regional CH4 emission



Toward assimilation of CONTRAIL data to estimate surface CO_2 fluxes

*Yosuke Niwa[1], Yousuke Sawa[1], Toshinobu Machida[2], Hidekazu Matsueda[1], Taku Umezawa[2], Nobuko Saigusa[2]

1.Meteorological Research Institute, 2.National Institute for Environmental Studies

Inverse modeling is a powerful method to elucidate carbon dioxide (CO_2) fluxes at the earth surface. Using the Bayesian algorithm, an inverse model quantitatively estimates spatiotemporal variations of surface fluxes from observations of atmospheric concentrations with help of a priori information. In this study, we have developed a new inversion system based on a state-of-the-art assimilation technique of the four-dimensional variational (4D-Var) method. Differently from a conventional method, the 4D-Var method has no limitation in the number of observations and it has an ability to estimate model grid resolution fluxes, so that regionally limited CO_2 flux anomalies such as biomass burnings are detectable. Since 2005, the aircraft measurement program named CONTRAIL has observed atmospheric CO_2 concentrations worldwide. Using the developed 4D-Var system, it is expected that such numerous aircraft data could strongly constrain the surface flux estimation especially for Asian regions. In this study, we discuss appropriate data processing or assimilation technique which is required before using the aircraft data in the flux estimation. Furthermore, we present conceivable impacts and valuable information provided by CONTRAIL for estimating Asian carbon budgets.

Keywords: carbon cycle, data assimilation, aircraft observation

Fine-scale CO_2 variations over the Tokyo megacity observed by CONTRAIL

*Taku Umezawa[1], Hidekazu Matsueda[2], Toshinobu Machida[1], Yousuke Sawa[2], Yosuke Niwa[2]

1.National Institute for Environmental Studies, 2.Meteorological Research Institute

Urban areas are considered to account for ~70% of the global anthropogenic carbon emissions. Many cities now take actions to reduce their carbon emissions. However, atmospheric CO_2 measurement networks capable of verifying carbon emissions from large cities are still far from sufficient. CONTRAIL, an ongoing project to measure trace gases with instruments onboard aircraft of Japan Airlines, has obtained millions of CO_2 data over worldwide large cities since 2005. In general, we have observed increases of CO_2 concentration approaching down to the airports, indicating presence of CO_2 plume over metropolitan areas. We found vertical gradient of CO_2 concentration (i.e. difference between the free troposphere and the lowermost layer) larger for large megacities, suggesting that CO_2 plume correlates with size of the city. This infers that the CONTRAIL measurements may have potential to assess city's carbon emission trends. In this study, we focus on detailed analysis of CO_2 distributions over Tokyo, currently the world largest megacity. Analyzing thousands of vertical profiles of CO_2 over the Narita and Haneda airports over the last 10 years, we found CO_2 levels significantly different between areas over Haneda and north and south of Narita. This likely reflects different catchments of CO_2 plumes over the respective areas.

Keywords: Megacity, CO2, Aircraft measurements

Influence of Fossil Fuel Emissions on CO_2 Flux Estimates by Atmospheric Inversions

*Tazu Saeki[1], Prabir K. Patra[1], Shinji Morimoto[2], Shuji Aoki[2]

1.Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2.Graduate School of Science, Tohoku University

Top-down approaches (or atmospheric inversions), using atmospheric transport models with CO_2 observations, are an effective way to estimate regional carbon fluxes. CO_2 flux estimates by Bayesian inversions require a priori knowledge of terrestrial biosphere exchanges, oceanic fluxes, and fossil fuel and cement production (FFC) CO_2 emissions. In most inversion frameworks, global and regional FFC CO_2 emissions are assumed to be a known quantity because FFC CO_2 based on world statistics are thought to be more reliable than natural CO_2 fluxes. However different databases of FFC CO_2 emissions may have different temporal and spatial variations especially at locations where statistics are not so accurate. In this study, we use 3 datasets of FFC emissions in inversion estimations and evaluate the sensitivity of the optimized CO_2 fluxes to FFC emissions with JAMSTEC's ACTM (an AGCM-based atmospheric chemistry-transport model) for the period of 2001–2011. Interannually varying a priori FF CO_2 emissions were based on 1) CDIAC database, 2) EDGARv4.2 database, and 3) IEA database, with some modifications. Biosphere and oceanic fluxes were optimized. Except for FF emissions, other conditions were kept the same in our inverse experiments. The three a priori FF emissions showed ~5% (~0.3GtC/yr) difference in their global total emissions in the early 2000's and the difference reached ~9% (~0.9 GtC/yr) in 2010. This resulted in 0.5–1 GtC/yr (average 2001–2011) difference in the estimated global total emissions for the ACTM inversions. Regional differences in the FFC emissions were relatively large in East Asia (~0.5 GtC/yr) and Europe (~0.4 GtC/yr). These a priori flux differences caused differences in the estimated biosphere fluxes in East Asia and Europe. Boreal North America and North Africa had less difference in FFC emissions but showed larger difference in estimated fluxes which might be affected by their neighboring regions.
Forward simulation results with the prior and posterior fluxes were compared with aircraft measurements over Japan by Tohoku University to validate the flux amplitudes and trends.
Acknowledgements. This work is supported by the Environment Research and Technology Development Fund (2-1401) of the Ministry of the Environment, Japan. We thank Ingrid T. van der Laan-Luijkx for providing IEA FF emission dataset.

Keywords: Carbon cycle, CO2, Inverse modeling

Development of anthropogenic pollutant emission inventory for India and its validation using satellite data

*Satoru Chatani[1], Sumit Sharma[2], Atul Kumar[2], Richa Mahtta[2]

1.National Institute for Environmental Studies, 2.The Energy and Resources Institute (TERI)

India is facing serious problems caused by heavy air pollution. Delhi has been ranked as the most polluted city in the world, and other 12 Indian cities have been also ranked within the top 20 polluted cities. It is urgently required to introduce effective strategies to improve air quality over India. Air pollution is caused by primary pollutants which are directly emitted by sources and secondary pollutants which are formed in the atmosphere from various precursors via complex photochemical reactions. Emission inventory which tabulates amount of emissions of primary pollutants and precursors emitted from various sources could be helpful to consider effective strategies.

This study has developed emission inventory of primary pollutants and precursors emitted from anthropogenic sources in India. The target sectors include domestic combustion, transport, industrial combustion, power plants, and non-energy sources. GAINS-Asia model were utilized to estimate CO, NOx, SOx, non-methane volatile organic compounds (NMVOCs) and particulate matter (PM) emissions based on information of emission factors, activities, and abatement technologies. Such information was collected from various reliable government and published data sources.

Estimated amount of CO, NOx, SOx, NMVOC and PM_{10} emissions in whole India is 53.8, 5.41, 7.03, 9.81, and 10.7 Tg for year 2010. The highest contributors to emissions are domestic combustion for CO and NMVOC, transport for NOx, power plants for SOx, and industrial combustion for PM_{10}.

In order to use the emission data in air quality simulations, the emissions were horizontally allocated to 36 x 36 kilometers meshes covering whole India based on district-wise information on registered vehicles and population, and state-wise information on industries. For large industries like cement, refineries, oil and gas explorations, iron and steel, thermal power plants, allocations were made at their exact location. The emissions of some sectors are vertically and temporally allocated based on information including traffic flows, time of cooking, and stack heights.

An air quality simulation using the regional chemical transport model, CMAQ version 5.0.2 were conducted to validate the emission data. The meteorological field was fed from the regional meteorology model, WRF version 3.7.1. In addition to the anthropogenic emissions developed in this study, GFED version 4.1 was used for biomass burning emissions, and MEGAN version 2.0.4 was utilized to estimated biogenic VOC emissions. The target domain consisted of 36 x 36 kilometers meshes includes several surrounding countries as well as whole India. The gridded emission database of ECLIPSE version 5a was used for the anthropogenic emissions from other surrounding countries than India. The gridded concentration fields simulated by the global chemical transport model, MOZART4 were provided as boundary concentrations.

The simulated results were compared with the satellite data. The retrieved values of aerosol optical depth (AOD) over the target domain in the MODIS level 2 dataset, and the simulated values at the corresponding locations and timings were picked up. While the simulation well reproduced features in a horizontal distribution of AOD indicating high aerosol loading over the Indo-Gangetic plains, its absolute level was underestimated. It is much important to improve emission inventory for not only anthropogenic sources but also missing sources including fugitive dust.

Keywords: Emission inventory, Air quality simulation, Satellite data

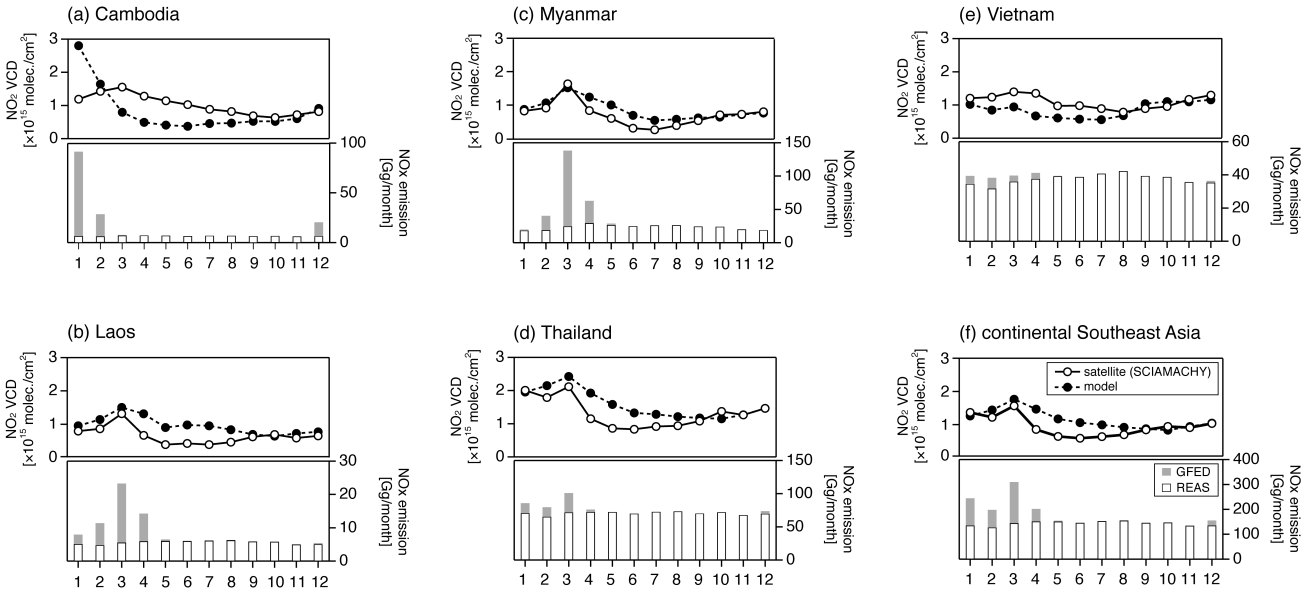
Examination of the impact from biomass burning emissions on NO_2 column density over Southeast Asia

*Syuichi Itahashi[1], Itsushi Uno[2], Hitoshi Irie[3], Jun-ichi Kurokawa[4], Toshimasa Ohara[5]

1.Central Research Institute of Electric Power Industry (CRIEPI), 2.Research Institute for Applied Mechanics (RIAM), Kyushu University, 3.Center for Environmental Remote Sensing (CEReS), Chiba University, 4.Asia Center for Air Pollution Research (ACAP), 5.National Institute for Environmental Studies (NIES)

In Southeast Asian countries, the emissions originated from biomass burning is one of the concerning issue during dry season. In this study, the impact from biomass burning emissions on the tropospheric NO_2 vertical column density (VCD) over continental Southeast Asia (Cambodia, Laos, Myanmar, Thailand, and Vietnam) was systematically analyzed using satellite observations by the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) and a regional chemical transport model (CTM) during 2003-2008. NO_2 VCD over continental Southeast Asia showed a distinctive large peak from winter (December) to early spring (April). The regional CTM was configured with anthropogenic emissions taken from the Regional Emission inventory in Asia (REAS) version 2.1 and biomass burning emissions taken from the Global Fire Emissions Database (GFED) version 3.1. Overall, the model could reproduce the NO_2 VCD observed by space-borne sensors. Mismatch between satellite observations and the regional CTM was found only in January over Cambodia. A likely reason for this mismatch was diurnal variation in biomass burning emissions. During the analysis period, the largest biomass burning event was reported from December 2003 to April 2004, and a sensitivity analysis was conducted by omitting the biomass burning emissions in the CTM. It was found that the seasonal variations of NO_2 VCD, with the peak during winter to early spring, were caused by biomass burning emissions in all countries in continental Southeast Asia. The contribution of biomass burning emissions to NO_2 VCD over continental Southeast Asia was an average of 28% during this period and a maximum of 58% in March 2004.

Keywords: Southeast Asia, Biomass burning emissions, NO2 vertical column density, Satellite observation, Regional chemical transport model



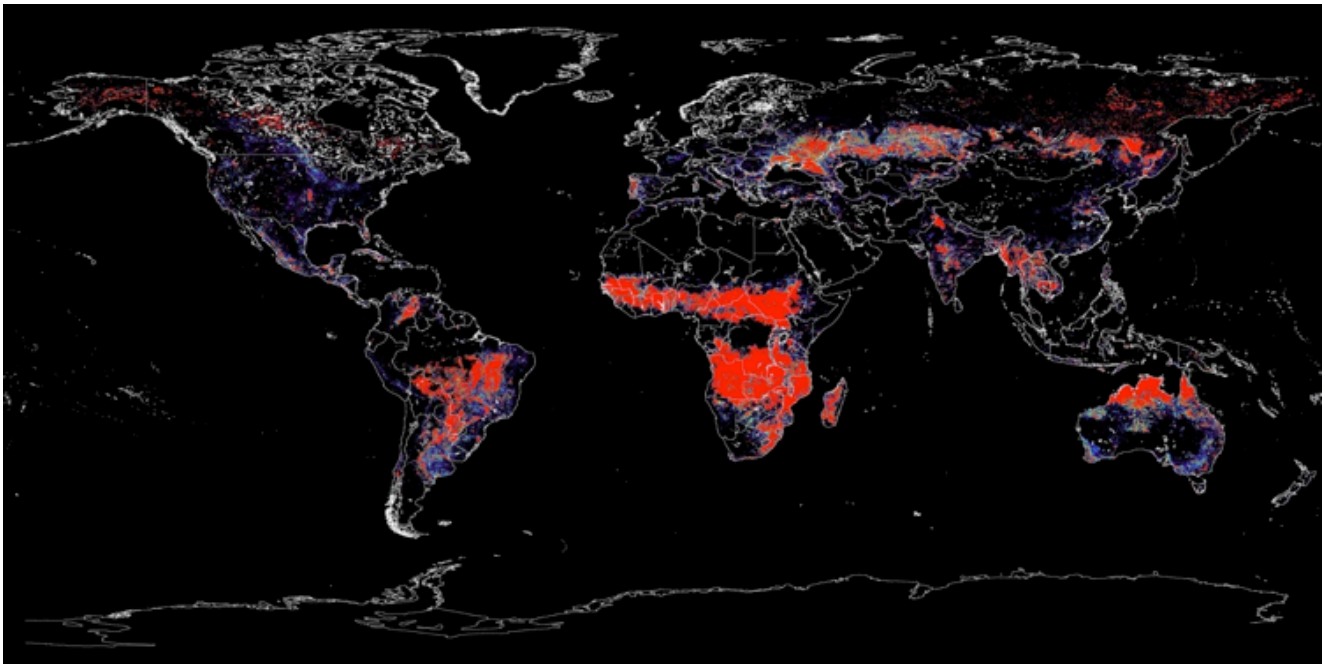
Estimation of global CO2 emission by biomass burning from 2001 to 2015

*Wataru Takeuchi[1], Soni Darmawan[1], Ryoichi Imasu[2]

1.Institute of Industrial Science, The University of Tokyo, 2.Atmosphere and Ocean Research Institute, The University of Tokyo

As a cause of global warming, CO2 is most effective green house gas and many countries are trying to reduce emission of that. However, the report of quantitative description is few still because the amount of CO2 emission is difficult to estimate for their complex process.This research is to devise a method to estimate the carbon dioxide (CO2) emissions from biomass burning such as forest fires and field burning in croplands in Global scale. The methodology consists of mainly three types of bio-physical parameters including (1) fire hotspots and radiative power measurements by MODIS thermal anomalies, (2) above ground biomass changes calibrated by MODIS NDVI and LAI indices, (3) ground water table modeled by MTSAT thermal anomalies and GSMaP rainfall measurements. Field campaigns were carried out from 2012 April to September in four types of land covers in (1) mangrove forest in Thailand and Vietnam (2) grassland in Mongolia (3) rice paddy field in Indonesia and Thailand and (4) forested peatland in Indonesia. Above ground biomass mapping of mangrove forest was investigated by ALOS PALSAR HH and HV polarimetric backscatter coefficients and an allometric equations derived by in-situ measurement of biomass parameters. That of grassland in Mongolia was mapped by MODIS LAI and NDVI, grassland height by ICESaT GLAS supplemented by in-situ observations. Rice paddy fields cropping patterns were mapped by MODIS NDVI and AMSR-E land surface water coverage parameters. Ground water table (GWT) was mapped to represent dryness over forested peatlands and the number of peat fires and peat decomposition were modeled with satellite-derived GWT and that of in-situ measurement. The estimated CO2 emissions from 2001 to 2015 were demonstrated and compared with Global Fire Emission Database version 4 (GFED 4) and EDGAR global database, and discrepancy between the models, challenges and technical problems were also discussed.

Keywords: land cover change, wild fires, emission inventory



Data-driven synthesis on terrestrial CO_2 budget changes in Asia

*Kazuhito Ichii[1,2], Prabir Patra[1], Masahito Ueyama[3], Masayuki Kondo[1], Nobuko Saigusa[2]

1.Japan Agency for Marine-Earth Science and Technology, 2.National Institute for Environmental Studies, 3.Osaka Prefecture University

Observational data provides a good constraint on understanding terrestrial CO_2 budget in a quantitative way. In recent years, more and more observation data (both satellite and ground observation) are being available, therefore, effective use of these data is an important step to improve our understandings of terrestrial CO_2 budget. In this presentation, we will show our recent progresses on the data-driven synthesis of terrestrial CO_2 budget in Asia. Topic includes (a) data-driven terrestrial CO_2 budget comparison in Asia as a continental scale case, and (b) satellite data analysis of large fire events in Southeast Asia in 2015 as a regional scale case.
The first part synthesizes results of data-driven top-down and bottom-up estimations of terrestrial CO_2 budget in Asia. We used an empirically upscaled estimation of terrestrial CO_2 budget using AsiaFlux data and remote sensing data (bottom-up approach) and GOSAT Level 4A product (top-down approach). The differences of the two estimation were explained by different definition of them in Siberia and East Asia. The empirically upscaled estimation is 'net ecosystem productivity', which is a difference of gross primary production and ecosystem respiration, and GOSAT L4A is land-atmosphere net CO_2 fluxes, which includes fire, dissolved inorganic carbon export through river, and land use changes. The Southeast Asia region shows large differences between the two estimations, implying the requirement of further research.
The second part focuses on analysis of forest fire in Southeast Asia. In 2015, an intense El Nino occurred, resulting in extremely low rainfall, anomalous fire were reported in Indonesia and countries in the tropical Asia. Using multiple satellite-based data, such as aerosol optical index, land surface temperature, active fire counts, and vegetation index, the large scale massive fire event in 2015 were analyzed. We clearly detected anomalous climate and fire occurrence in Southeast Asia during August to October from MODIS active fire counts, and aerosol optical index. These data shows strong anomalous patterns compared with the normal year. We analyzed the cause of more frequent fire events in El Nino years, and found that persistent negative anomalies in precipitation is most strongly correlated with fire frequency at interannual time scales.
Acknowledgement
This study was supported by the Environment Research and Technology Development Funds (2-1401) from the Ministry of the Environment of Japan, the JAXA Global Change Observation Mission (GCOM) project (grant No. 115), and the JSPS KAKENHI (grant No. 25281003).

Keywords: Material Cycle, Asia, Fire, Terrestrial Biosphere

Network connection of tower flux measurement data :Toward long term stable flux measurement

*Yuji Kominami[1], Katsumi Yamanoi[1], Kenzo Kitamura[1], Takafumi Miyama[1], Yasuko Mizoguchi[1], Satoru Takanashi[1], Yukio Yasuda[1], Nobuko Saigusa[2], Yoshiyuki Takahashi[2], Wonsik Kim[4], Akira Miyata[4], Keisuke Ono[4], Shigeyuki Ishidoya[3], Hiroaki Kondo[3], Takahisa Maeda [3], Shohei Murayama[3], Samreong Panuthai[5], Taksin Archawakom[6]

1.Foresry ansd Forest Products Research Institute , 2.National Institute for Environmental Studies, 3.National Institute of Advanced Industrial Science and Technology, 4.National Institute for Agro-Environmental Science, 5.Department of National Park, Wildlife, and Plant Conservation of Thailand, 6.Thailand Institute of Scientific and Technological Research

Since last half of 1990's, many flux towers have been constructed mainly for monitoring CO_2 flux using eddy covariance method at various land ecosystems in the world. And much effort have been made to keep data quality. Comparing with standard environmental factors (e.g. sun radiation, wind speed), eddy covariance measurement requires sensitive equipment (infrared CO_2 gas analyzer and supersonic anemometer), frequent maintenance and severe data quality are necessary. On the other hand, to evaluate the effect of land ecosystem to global climate change, long term and quality certified data are demanded. We, 4 national research institutes, constructed and have maintained 11 CO_2 flux measurement towers in Japan and East Asia (Fig.1, 8 in Japan and 3 in East Asia countries). To reduce effort of maintenance and increase data quality, we have conducted following contrivances supported by Environmental Agency Fund.
1. For quick check of flux measurement devices and data quality, we constructed the system to integrate whole flux site data in a data saver at Tsukuba using network.
2. To reduce effort of data analysis, we set up standardized flux data format and developed an automated flux data analyze system.
3. To check each site data quality, we developed a mobile closed pass CO_2 flux measurement system
4. For quick learning of flux measurement technique, we published a flux measurement manual (http://www2.ffpri.affrc.go.jp/labs/flux/manual/FluxManual_Ver1.1b.pdf)

Keywords: CO2 flux, Land ecosystem, Flux tower

Fig.1 11 tower flux sites in Asia

Proportion of atmospheric methane to carbon dioxide observed by GOSAT over biomass burning regions in Africa

*Sachiko Hayashida[1], Okiko Ono[1]

1.Faculty of Science, Nara Women's University

Multi-species satellite measurements in important biomass burning regions are expected for better understanding the partitioning of reduced gas production (van der Werf, 2010). In this study, we utilized the data of atmospheric concentration of carbon dioxide (CO2) and methane (CH4) observed by Thermal And Near-infrared Sensor for carbon Observation (TANSO)-FTS onboard Greenhouse Gases Observing Satellite (GOSAT) to derive the ratios of the two species over the active biomass burning regions in Africa. Contribution of fire emission from Africa to the global carbon fire emissions is estimated as 52% by van der Werf (2010). It is well recognized that in Northern Hemisphere Africa (NHA), fires occur primarily in the Sahel between November and February. On the other hand, in Southern Hemisphere Africa (SHA), fires are prominent primarily between June and October (e.g., Roberts, et al. 2009). We investigated the proportions of CH4 to CO2 focusing on regions and seasonality and found the proportion of CH4 to CO2 during the burning season over NHA is higher than that in SHA. In addition to CH4 and CO2, we are going to show the results of combined analysis with carbon monoxide (CO) observed by Measurements Of Pollution In The Troposphere (MOPITT), and discuss potential of satellite sensors to characterize biomass burning.
References
Roberts et al. (2009): Biogeosciences, 6, 849-866.
van der Werf et al. (2010): ACP, 10, 11707-11735.

Keywords: carbon cycle, biomass burning, GOSAT

Relationships between CO_2 flux estimated by inverse analysis and land surface elements in South America and Africa

*Kazuo Mabuchi[1], Hiroshi Takagi[1], Shamil Maksyutov[1]

1.National Institute for Environmental Studies

Inverse analysis estimates the regional flux of greenhouse gases between the earth's surface and the atmosphere by using observed atmospheric concentration data that include satellite data. In particular, this method is effective in estimating the flux in regions where observational flux data are limited. However, inverse analysis is basically a mathematical optimization method. Therefore, confirmation of the causal validity of the spatial and temporal changes in the estimated flux is necessary. One confirmation method is validation of the relationship with physical and biological observation data (analysis data) of confirmed accuracy. In this study, the features and validity of changes in the CO_2 flux estimated by inverse analysis were verified by interrelation analysis with changes in precipitation, short-wave radiation, surface temperature, and Normalized Difference Vegetation Index (NDVI) in regions of South America and Africa where CO_2 flux observation data are limited. Sufficient accuracy of the land surface elements is required for the analysis results to confirm the CO_2 flux estimated by inverse analysis. An examination of the correlation of anomalies showed consistent relationships among the precipitation, short-wave radiation, surface temperature, and NDVI data used in this study, which were created independently. The relationships between change in the estimated CO_2 flux and characteristic changes of the land surface elements in South America and Africa were consistent in each region. This study confirmed the physical and biological validity of the changes in the CO_2 flux estimated by inverse analysis. During the period of this study, the NDVI anomaly was influential in South America, and the precipitation (soil wetness) anomaly was an essential factor in Africa for the CO_2 flux anomaly. The short-wave radiation anomaly was also influential in both South America and Africa. These relationships are detected more clearly in the results of inverse analysis using both ground-based CO_2 concentration data and GOSAT satellite data than in the results using only ground-based CO_2 concentration data. This demonstrates the usefulness of GOSAT data in regions with limited atmospheric CO_2 concentration data.

Keywords: inverse simulation analysis, CO2 flux, land surface element

Analysis of methane concentration variation observed by GOSAT in Sichuan Basin, China and its relationship with local sources

*XIUCHUN QIN[1], Masahiro Kawasaki[1], Masafumi Ohashi[2], Tomoki Nakayama[1], Yutaka Matsumi[1], Liping Lei[3], Zhonghua He[3], Zhaocheng Zeng[4]

1.Nagoya university Institute for Space-Earth Environmental Research, 2.Kagoshima University, 3. Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, 4.The Chinese University of Hong Kong

Atmospheric Methane (CH_4) is one of the most important greenhouse gases, and the greenhouse effect generated by unit molecule of CH_4 is about 23 times higher than that of atmospheric Carbon Dioxide (CO_2). Therefore, it will be more effective to reduce the CH_4 emissions to mitigate the potential global warming than reducing CO_2 emissions. The increase of global atmospheric CH_4 concentration is mainly due to agricultural activities, in which irrigated rice paddy is one of the most important sources. China is the world's largest rice producer, accounting for about 22% of the rice planting area in the world and 37% of the global production. Therefore, studies of China's regional CH_4 emissions and its driving factors are of importance to understand the regional and global carbon cycle and the changing climate. In this study, XCH_4 observations from GOSAT, spanning from January 2010 to December 2013, are analyzed to study the spatio-temporal variation of XCH_4 in China and its relationship with regional surface emissions. In further, we investigate the driving mechanism of XCH_4 spatio-temporal variations, especially for high XCH4 values shown over Sichuan Basin in south-west China, by combining the emission mechanism of rice planting process, the meteorology data, the surface emission data and the regional atmosphere dynamic transportation.

The results indicate that spatially the Sichuan Basin presents a higher XCH4 concentration than other regions in China and is 17 ppb higher than the paddy area in the same latitude zone. Seasonally, XCH4 in Sichuan Basin during rice harvest season is generally higher than that in early cultivation period. However, comparing to paddy area in the same latitude zone, Sichuan Basin shows a relatively higher XCH4 value during the winter of noncultivation period when the emissions from rice paddies are weak and surface air temperature is low. To further investigate the high XCH4 concentration during this low-emission period, we use the HYSPLIT model to simulate the atmosphere dynamic transport process, and the result suggests that the typical closed topography of Sichuan Basin, which may lead to CH4 accumulation and keep it from diffusion, is one possible reason for the high XCH4 value in winter.

Our result from studying the CH_4 variations in Sichuan Basin, especially the abnormal higher value during winter, and their driving factors demonstrate a certain potential of using GOSAT-XCH_4 for investigating the regional CH_4 changes. This study presents preliminary results of CH_4 in China, and a further investigation of the CH_4 in the basin is still necessary as more satellite observations of CH_4 with improving accuracy are available in the coming future to further study the CH_4 variations and regional emissions.

[1]Xiuchun Qin, Liping Lei, Zhonghua He, Zhao-Cheng Zeng, Masahiro Kawasaki, Masafumi Ohashi, and Yutaka Matsumi, “Preliminary Assessment of Methane Concentration Variation Observed by GOSAT in China”, Advances in Meteorology,2015, DOI: 10.1155/2015/125059

Keywords: GOSAT, XCH4, paddy field emission, atmosphere transmission, topography

Development of Carbon cycle analysis system using satellite data and LETKF

*Takashi Maki[1], Takashi Nakamura[4], Tsuyoshi Thomas Sekiyama[1], Takemasa Miyoshi[2], Toshiki Iwasaki[3]

1.Meteorological Research Institute, 2.RIKEN, 3.Graduate School of Science, Tohoku University, 4.Japan Meteorological Agency

We have developed satellite data assimilation system using CO2 concentration data obtained from satellite measurements using an ensemble-based four-dimensional data assimilation system (LETKF). An online atmospheric transport model (MJ98-CDTM) is employed in the data assimilation system to optimize surface CO2 fluxes from satellite observations at spatial and temporal resolutions of 6 days and 2.8°, respectively. The features of GOSAT TIR L2 Ver. 1.0 data are their larger data number than that of SWIR L2 (about 10 times) and smaller standard deviation than their former version (TIR L2 Ver. 0.01). We have tested 4 types of satellite bias correction methods (w/o bias correction, monthly mean bias correction, all data bias correction and globally constant bias correction) using independent CO2 concentration analysis (JMA CO2 distribution) in our data assimilation system. Our results showed that estimated CO2 concentration and fluxes are significantly sensitive to bias correction method. This means that we should carefully choose satellite bias correction method. In addition, satellite data bias correction allows modifying surface CO2 flux almost entire earth surface. In the future, our satellite bias correction concept makes it possible to use multiple satellite observation data simultaneously in CO2 data assimilation.

Keywords: Carbon Cycle, Data Assimilation, Satellite Observation

Estimation of global surface fluxes of a greenhouse gas with LETKF data assimilation system

*Ryu Saito[1], Prabir K Patra[2], Tazu Saeki[2], Kazuyuki Miyazaki[2]

1.KOKUSAI KOGYO CO., LTD, 2.JAMSTEC

We present global CO_2 flux estimations using the local ensemble transform Kalman filter (LETKF) system with the GOSAT obtained XCO_2 and the WDCGG compiled CO_2 concentration data. In the previous study [Miyazaki et. al., 2011], a performance of the LETKF system was evaluated using GOSAT column pseudo-data in reference and the other various types of CO_2 concentration data. Here, we use the GOSAT retrievals to estimate the flux with the 4-D data assimilation system.
The data assimilation system used in this study was developed by Miyazaki et al., 2011, on the basis of the LETKF scheme [Miyoshi et al.]. A basic methodology of the LETKF follows the original EnKF [Ott et al., 2004; Hunt et al., 2007].The covariance localization [Houtekamer and Mitchell, 2001] is used to remove long range spurious correlations. The state vector augmentation method [Anderson, 2001; Aksoy et al., 2006; Tong and Xue, 2008] has been applied to simultaneously estimate the atmospheric CO_2 concentration as model states together with the surface CO_2 flux as uncertain model parameters. The surface fluxes at every model grid points are analyzed with 4-daily assimilation window during 2012 year. The ensemble size is hundreds. The transport model is coupled with the Center for Climate System Research/National Institute for Environmental Studies/Frontier Research Center for Global Change (CCSR/NIES/FRCGC) atmospheric general circulation model (AGCM) version 5.7b [Numaguti et al., 1995]. The model spatial resolutions are horizontally T42 truncation (approximately 2.8 degree) and vertically 32 levels up to 7 hPa. The surface CO_2 concentrations used in this study are obtained with the flask sampling data observed at sites in the surface network, which is archived at the WDCGG, and the XCO_2 concentrations are retrieved from GOSAT soundings using the RemoTec algorithm [Butz et al., 2009]. These observational data assimilate into the transport model. The LETKF system performance is evaluated by error reduction ratio of the posterior to prior ensemble fluxes.
We show analysis results that are the error reduction ration depending on various types of the observational data and seasonal variability of the optimized fluxes over aggregated land scale.
Acknowledgements. The authors thank the RemoTeC Proxy products retrieved from GOSAT TANSO-FTS SWIR spectra using the RemoTeC algorithm that is being jointly developed at SRON Netherlands Institute for Space Research and the Karlsruhe Institute for Technology (KIT).

Keywords: Carbon cycling, Ggreenhouse gas, Data assimilation, LETKF

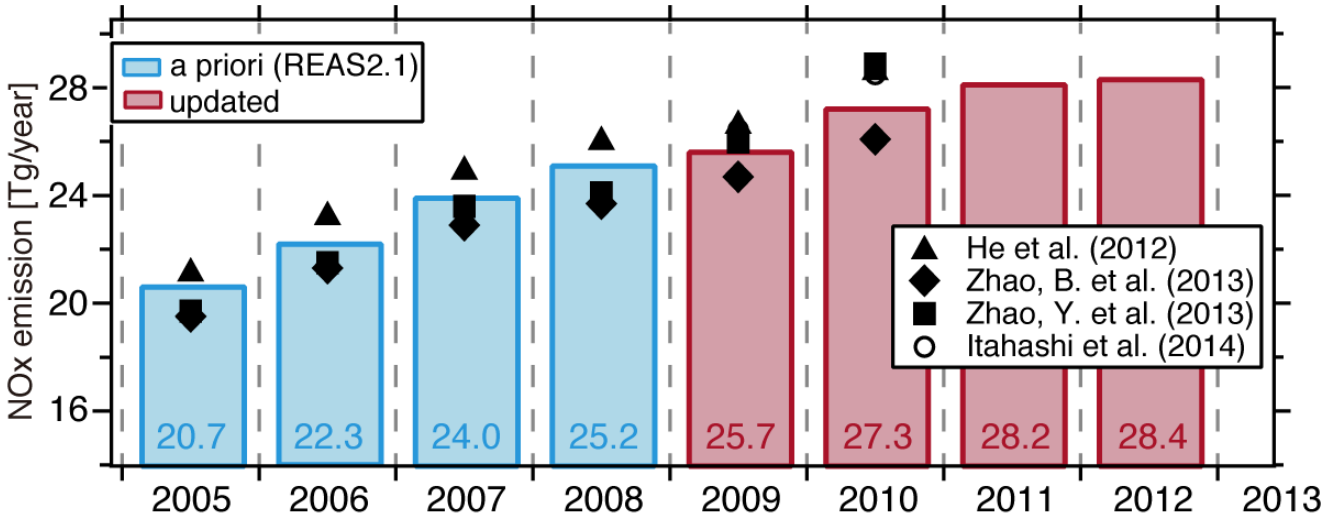
Application of Inversion Technique to Quick Update of Anthropogenic NO_x emission over East Asia with Satellite Observations and Chemical Transport Model

*Keiya Yumimoto[1], Itsushi Uno[2], Syuichi Itahashi[3], Kazuyuki Miyazaki[4]

1.Meteorological Research Institute, 2.Research Institute for Applied Mechanics, Kyushu University, 3.Central Research Institute of Electric Power Industry, 4.Japan Agency for Marine-Earth Science and Technology

We developed a quick update system for an emission inventory with an inversion technique, and extended NO_x emission in Regional Emission inventory in the ASia version 2.1 (REAS 2.1) through 2009-May 2013 with satellite-observed tropospheric NO_2 vertical column densities (VCDs) and a chemical transport model. The observed NO_2 VCDs over the eastern Chinese region exhibited a drastic inter-annual variation over the eastern Chinese region due to the socioeconomic condition. During 2008-2009, the growing of the NO_2 VCD became sluggish because of pollutant controls by the 2008 Beijing Olympic game and the global depression, but revived in 2010 with a growth rate of 37.3%/year. The modeled NO_2 VCD with the updated emission successfully followed the inter-annual variation, and reproduced the observed seasonal cycle in which summer and winter have the seasonal bottom and peak, respectively. We estimated the updated Chinese anthropogenic NO_x emissions during 2009-2012 to be 25.7, 27.3, 28.2, 28.4 Tg/year; they fell within the range of the various estimates in the literatures. An annual growth rate during 2009-2012 and 2005-2012 was estimated to be 3.5%/year (0.9 Tg/year) and 5.3%/year (1.1 Tg/year), respectively. The system has the capability of updating NO_x emission in near real-time (NRT) for air qualtiy forecasting. Figure shows annual anthropogenic NO_x emission from China. Numbers in the panels represent annual Chinese anthropogenic NO_x emission. Other estimates of Chinese NO_x emission are also shown by symbols.

Keywords: Inversion, Emission inventory, Chemical transport model, Satellite observation, NOx emission



Characteristics of Version 1.0 CO_2 data retrieved from TIR band of GOSAT/TANSO-FTS

*Naoko Saitoh[1], Shuhei Kimoto[1], Ryo Sugimura[1], Ryoichi Imasu[2], Kei Shiomi[3], Akihiko Kuze[3], Toshinobu Machida[4], Yousuke Sawa[5], Hidekazu Matsueda[5]

1.Center for Environmental Remote Sensing, Chiba University, 2.Atmosphere and Ocean Research Institute, University of Tokyo, 3.Japan Aerospace Exploration Agency, 4.National Institute for Environmental Studies, 5.Meteorological Research Institute

Greenhouse Gases Observing Satellite (GOSAT) was launched on 23 January 2009, and has continued to make global observations of greenhouse gases, including both nadir and off-nadir measurements, for more than seven years since its launch. Carbon dioxide (CO_2) concentrations in several atmospheric layers can be retrieved from radiance spectra of the thermal infrared (TIR) band of Thermal and Near-infrared Sensor for Carbon Observation Fourier Transform Spectrometer (TANSO-FTS) on board the GOSAT. We have analyzed the latest released version of the TIR Level 2 (L2) CO_2 product (Version 1.0). We compared TANSO-FTS TIR V1.0 CO_2 data and CO_2 data obtained in the Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL) project. The comparisons over several airports showed that the TIR V1.0 CO_2 data had a 1-2% negative bias in the middle troposphere; the magnitude of the bias varied seasonally and regionally. The comparisons in the upper troposphere and lower stratosphere (UTLS), where the TIR band of TANSO-FTS is most sensitive to CO_2 concentrations, showed that the averages of the TIR upper atmospheric CO_2 data agreed well with the averages of the data obtained by the CONTRAIL Continuous CO_2 Measuring Experiment (CME) within 0.1% and 0.5% for all of the seasons in the Southern and Northern Hemisphere, respectively. The magnitude of bias in the TIR upper atmospheric CO_2 data did not have a clear longitudinal dependence. The comparison results for flights in northern low and middle latitudes showed that the agreement between TIR and CONTRAIL CO_2 data in the upper troposphere was worse in the spring and summer than in the fall and winter. The negative bias in northern middle latitudes made the maximum of TIR CO_2 concentrations lower than that of CONTRAIL CO_2 concentrations, which leads to underestimate the amplitude of CO_2 seasonal variation. CO_2 growth rate estimated from the TIR UTLS CO_2 data from 2010 to 2012 was slightly lower (-0.6 ppm) than that from the CONTRAIL level flight data during the same period, which increases the differences between TIR and CONTRAIL CO_2 concentrations in UTLS.

Keywords: satellite remote sensing, retrieval algorithm, validation analysis, CO2

Validation of GOSAT SWIR XCO_2 and XCH_4 retrieved by PPDF-S method

*Chisa Iwasaki[1], Sachiko Hayashida[2], Ryoichi Imasu[1], Tatsuya Yokota[3], Isamu Morino[3], Yukio Yoshida[3]

1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Nara Women's University, 3.National Institute for Environmental Studies

We focused on column averaged dry air mole fraction of atmospheric CO_2 and CH_4 (XCO_2 and XCH_4, respectively) retrievals from Greenhouse gases Observing Satellite (GOSAT) measurements through the photon path length probability density function (PPDF-S) based retrieval method that simultaneously retrieves target gas abundance and PPDF parameters. This method is used for an effective retrieval algorithm even under high concentration of clouds and aerosols. First, we validated PPDF-S XCO_2 and XCH_4 retrievals by comparing them with ground-based observations provided by the Total Carbon Column Observing Network (TCCON) from June 2009 to May 2014. For comparison, we also validate retrievals through another algorithm using full physics (FP)-based retrieval method. PPDF-S and FP retrieval methods are different in way to account for light scattering effect. All these XCO_2 and XCH_4 retrievals are provided by the National Institute for Environmental Studies (NIES). PPDF-S retrievals have positive biases (0.47 ±2.11 ppm for XCO_2 and 0.76 ±15.49 ppb for XCH_4), on the other hand, FP retrievals have negative biases (-0.28 ±2.34 ppm for XCO_2 and -2.16 ±13.26 ppb for XCH_4). Next, we compare global maps of XCO_2 and XCH_4 mean value, standard deviation and number of data between PPDF-S and FP retrievals. Over the ocean, PPDF-S method can retrieve large number of data whose standard deviation is larger than FP method. These PPDF-S retrievals over the ocean include data which are eliminated in post-screening process for FP method to exclude data that are strongly affected by clouds and aerosol.

Keywords: GOSAT, retrieval, carbon dioxide, methane

Global carbon budget estimation based on atmospheric oxygen and carbon dioxide observation during recent 15-year period

*Yasunori Tohjima[1], Mukai Hitoshi[1], Toshinobu Machida[1], Shin-ichiro Nakaoka[1]

1.National Institute for Environmental Studies

Time series of atmospheric O_2/N_2 ratio and CO_2 mixing ratio of flask samples taken from NIES's flask sampling network are presented. The network includes ground sites, Hateruma Island (lat 24°03'N, long 123°48'E) and Cape Ochi-ishi (lat 43°10'N, long 145°30'E), and cargo ships regularly sailing in the Pacific region. The air samples collected in Pyrex glass flasks were sent back to our laboratory and the O_2/N_2 ratio and CO_2 mixing ratio were analyzed by using a GC/TCD and NDIR analyzers. Taking into account the global mass balances of atmospheric CO_2 and O_2, we estimate the global carbon sequestration rates of the ocean and land biosphere for the recent 15-year period. In this carbon budget calculation, we use the secular changes in the atmospheric O_2 and CO_2 burdens based on our flask observations and the fossil fuel-derived CO_2 emissions based on energy statistics. We also adopt the ocean O_2 outgassing fluxes (~0.5 PgC/yr), which is estimated from secular changes in the ocean heat content (0-2000m) and an estimated O_2-to-heat flux ratio. For example, the oceanic and land biotic carbon sequestration rates for the 15-year period (1999-2014) calculated from the observation at Hateruma Island are 2.4±0.7 Pg-C yr^{-1} and 1.5±0.8 Pg-C yr^{-1}, respectively. In the presentation, we also examine the temporal changes in the global carbon budgets and compare our estimations with the other reported carbon budget estimations.

Keywords: global carbon budget, oxygen, carbon dioxide

Achievements and Future Visions: Monitoring Carbon Cycle Change using an Integrated Observation, Modeling and Analysis System

*Nobuko Saigusa[1], Toshinobu Machida[1], Prabir Patra[2], Yosuke Niwa[3], Kazuhito Ichii[2]

1.National Institute for Environmental Studies, 2.Japan Agency for Marine-Earth Science and Technology, 3.Meteorological Research Institute

We are developing 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) are strengthened based on the “Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL)” project. Atmospheric transport modeling, inverse modeling, and assimilation methods are being developed and improved for better utilization of observational data from the Asia-Pacific region. Global and regional surface fluxes are estimated by both "top-down” approach using inverse models and "bottom-up” approach using surface flux observation network data (e.g. AsiaFlux) and upscaling with terrestrial ecosystem models.
We will present current progress for better constraints of global, continental, and regional carbon budgets, and detection of carbon cycle change particularly in the Asia-Pacific. We also would like to raise following questions and discuss how to solve them in the next steps.
1) How can the current capabilities of top-down and bottom-up approaches contribute to reduce uncertainties in the estimates of large anthropogenic emissions? (e.g. fuel use, land use changes, and rapid urbanization)
2) What are the key target regions or events in the Asia-Pacific that we need to focus on? (e.g. El Niño-induced droughts, extreme forest fires in Southeast Asia, and peat degradations in tropical and boreal regions)
3) How should the current capabilities of observation, modeling and analysis systems be integrated into an operational system for long-term monitoring of changes in regional, continental, and global GHGs budgets?
4) What are the urgent requirements to realize such system? (e.g. strategies of more intensive observations in targeted area, and a platform for multi-model ensemble)
5) How can we provide scientific knowledge and data timely for evaluating mitigation and adaptation policies?

Keywords: Carbon Cycle, Integrated Observation and Analysis System, Asia-Pacific

Synthesis of top-down and bottom-up estimations of terrestrial CO_2 budget in Asia

*Kazuhito Ichii[1,2], Masayuki Kondo[1], Prabir Patra[1], Tazu Saeki[1], Takashi Maki[3], Takashi Nakamura[4], Yosuke Niwa[3], Masahito Ueyama[5], Masato Hayashi[2], Habura Borjigin[2], Yuji Yanagi[1], Nobuko Saigusa[2], Asia-MIP Group

1.Japan Agency for Marine-Earth Science and Technology, 2.National Institute for Environmental Studies, 3.Meteorological Research Institute, 4.Japan Meteorological Agency, 5.Osaka Prefecture University

In the framework of Environment Research and Technology Development Funds (2-1401) from the Ministry of the Environment of Japan, we initiated synthesis analysis toward better estimations and understandings of terrestrial CO_2 budget in Asia. We used multiple different data products such as atmospheric inverse analysis (top-down estimation), terrestrial ecosystem models, remote sensing data, and data-driven models (bottom-up estimation). Our analysis focuses on (1) inter-decadal changes in terrestrial CO_2 fluxes at continental scales (Asia and Siberia), (2) testing consistency of terrestrial sink magnitude between top-down and bottom-up estimations in Asia, and (3) detection and analysis of 'hotspot' of terrestrial CO_2 budget changes in Siberia and tropical Asia. We will show these progresses, and discuss future direction of these studies.

Acknowledgement
This study was supported by the Environment Research and Technology Development Funds (2-1401) from the Ministry of the Environment of Japan, and the JSPS KAKENHI (grant No. 25281003).

Keywords: Terrestrial, Synthesis, Carbon Dioxide

The potential of spaceborne LiDAR for precise forest resources observation

*Masato Hayashi[1], Nobuko Saigusa[1], Yoshiki Yamagata[1]

1.National Institute for Environmental Studies

Satellite remote-sensing is suitable for a large scale observation of forests, and spaceborne light detection and ranging (LiDAR) is a novel sensor that can be used for accurate measurement. Spaceborne LiDAR is an active sensor to transmit laser pulses, and it records the changes in return laser energy intensity as a waveform, and the waveform contained information on the vertical structure of forests. The only spaceborne LiDAR so far has been the Ice Cloud and land Elevation Satellite (ICESat)/ Geoscience Laser Altimeter System (GLAS), operated by NASA from 2003 to 2009. Many previous studies have applied GLAS data to forest observation, and they mostly estimated two essential parameters of forest resources: canopy height and aboveground biomass. We also applied ICESat/GLAS spaceborne LiDAR data to three forested areas: Hokkaido Island in Japan (cool-temperate forest), Borneo Island (tropical forest), and Siberia (boreal forest). As a result, we revealed the distribution of canopy height and aboveground biomass in the study areas. Furthermore, we implemented the following: (1) quantitative estimates of canopy height change according to typhoon disturbance in Hokkaido, (2) estimation of yearly forest loss rate in Borneo, and (3) hot spots detection of forest change in Siberia. In this way, spaceborne LiDAR enables us to observe forest resources accurately at each footprint point. However, an analysis combined with the other imagery data should be needed for entirely forest monioring, and the methodology has been studied in recent years. There are some plans of spaceborne LiDARs launched within a few years, and they will play an important role in global forest resources monitoring in the future.

Keywords: Canopy height, Forest biomass, Spaceborne LiDAR, ICESat/GLAS

Development of a low-cost in-situ methane observation system and results of field observation at a paddy field in India

*Masaya Izuhara[1], Takehiro Hidemori[1], Masahiro Kawasaki[1], Tomoki Nakayama[1], Yutaka Matsumi[1], Hiroshi Sasago[1], Yukio Terao[2], Shohei Nomura[2], Toshinobu Machida[2], Wataru Takeuchi[3], Minaco Adachi[4], Ryoichi Imasu[5], Surendra Kumar Dhaka[6], Jagmohan Singh[6], Kenshi Takahashi[7]

1.Institute for Space-Earth Environmental Research, Nagoya University, 2.National Institute for Environmental Studies, 3.Institute for Industrial Science, the University of Tokyo, 4.Graduate School of Life and Environmental Sciences, University of Tsukuba, 5.Atmosphere and Ocean Research Institute, the University of Tokyo, 6.Rajdhani College, University of Delhi, 7.Research Institute for Sustainable Humanosphere, Kyoto University

Methane (CH_4) is the second most prevalent greenhouse gas next to carbon dioxide (CO_2). The atmospheric concentration of methane tends to increase year by year, and it is important to obtain detail information on the source of methane and seasonal variation of its concentration. Since there are many unclear points about the regional differences and seasonal variations of the methane concentration, further ground-based observations are needed to investigate them in detail. Previous studies suggest that the emissions of methane from farmlands in Southeast and South Asia have significant contribution to the methane concentrations. But, there are many difficulties to conduct observations in such farmlands. At the paddy field in north India where we plan to observe methane, electric power are available for only 2-3 hours a day at night and the duration of power supply is not stable. In addition, the place where we can set the measurement instrument is nothing but a barn in the farmland, and we must manage to prevent bad influences on instruments by rain, dust, bugs, and rats. Thus, it is difficult to use existing commercial instruments, which are typically operated in a clean laboratory. Therefore, we developed a low-cost measurement system of methane to use at rural and remote area. Moreover, we have conducted the methane measurement using the developed system at the paddy field in India.

In this study, we used LaserMethane(ANRITSU Co. Ltd.) to measure the atmospheric concentrations of methane. LaserMethane is the portable instrument with low electricity consumption, which can measure methane concentrations in real time. LaserMethane is an open-path laser spectroscopic instrument which can measure methane selectively by tunable diode laser absorption spectroscopy. We developed a power supply, a data logging, and a remote control equipment for continuous operation of LaserMethane at remote area. We have conducted the methane observation at Sonipat, Haryana in India which is located at north of Delhi since the end of 2014 using the developed system. Along with LaserMethane, we have also obtained methane concentrations from the off-line analyses of ambient air, which have been sampled typically once a week, using gas chromatography. The concentration data of LaserMethane are calibrated by the air sampling data and meteorological data. In this presentation, we will present the introduction of the developed system and the measurement results which were obtained in 2015 at the paddy field in Sonipat, India. It showed that the concentrations of methane increased in monsoon season and winter. This characteristic enhancement of methane concentrations observed in monsoon season is considered to be due to the large methane emission from paddy field during rice cultivation. In addition, the real-time measurements indicated that the large variation of methane concentrations between day and night often appeared. We will also discuss the sources of the observed seasonal and diurnal variations.

Reference

Matsumi et al., Measuring methane with a simple open-path gas sensor, SPIE Newsroom, doi: 101117/2.1201601.006283, 2016

http://spie.org/newsroom/technical-articles/6283-measuring-methane-with-a-simple-open-path-gas-sensor

Keywords: in-situ methane measurement system, field observation in India, rice paddy field

Annual variaiton of soil respiriration in subtropical afforetation forest in Taiwan

*PoNeng Chiang[1], Jui-Chu Yu[1], Yen-Jen Lai[1]

1.Experimental Forest, National Taiwan University

Global forests contain 69% of total carbon stored in forest soil and litter. But the carbon storage ability and release rate of warming gases of forest soil also affect global climate change. Soil carbon cycling processes are paid much attention by ecological scientists and policy makers because of the possibility of carbon being stored in soil via land use management. Soil respiration contributed large part of terrestrial carbon flux, but the relationship of soil respiration and climate change was still obscurity. Most of soil respiration researches focus on template and tropical area, little was known that in subtropical area. Afforestation is one of solutions to mitigate CO2 increase and to sequestrate CO2 in tree and soil. Therefore, the objective of this study is to clarify the relationship of tree species and soil respiration distribution in subtropical broad-leaves plantation in southern Taiwan. The research site located on southern Taiwan was sugarcane farm before 2002. The sugarcane was removed and fourteen broadleaved tree species were planted in 2002-2005. Sixteen plots (250m*250m) were set on 1 km2 area, each plot contained 4 subplots (170m2). The forest biomass (i.e. tree height, DBH) understory biomass, litter, and soil C were measured and analyzed at 2011 to 2015. Soil respiration measurement was sampled in each subplot in each month. The soil belongs to Entisol with over 60% of sandstone. The soil pH is 5.5 with low base cations because of high sand percentage. Soil carbon storage showed significantly negative relationship with soil bulk density ($p<0.001$) in research site. The differences of distribution of live tree C pool among 16 plots were affected by growth characteristic of tree species. Data showed that the accumulation amount of litterfall was highest in December to February and lowest in June. Different tree species planted in 16 plots, resulting in high spatial variation of litterfall amount. It also affected total amount of litterfall temporal variation. Soil respiration was related with season variation in research site. Soil temperature and soil respiration showed highly spatial variation in 16 plots. Soil temperature showed significantly exponential related with soil respiration in research site ($p<0.001$). Annual soil temperature was decrease with tree age increasing in this 5 years. Annual soil respiration was showed decrease with tree age increasing. However, soil respiration showed significantly negative relationship with total amount of litterfall ($p<0.001$), suggesting that the tree was still young and did not reach crown closure.

Keywords: Soil respiration, Plantation, Spatial Variation

Spatial and temporal seasonal variation of CO_2 efflux from the soil surface in the boreal forests in Central Siberia

*Anastasia Vladimirovna Makhnykina[1], Anatoly Stanislavovich Prokushkin[2], Sergey Vladimirovich Verkhovets[1], Nataly Nikolaevna Koshurnikova[1]

1.Siberian Federal University, 2.V.N. Sukachev Institute of forest of Siberian Branch RAS

In boreal forest ecosystems, soil CO_2 flux may account for 40–80 % of the total CO_2 release in forest ecosystems [4], and it is the main pathway of transferring carbon from terrestrial ecosystems to the atmosphere. The amount of CO_2 released to the atmosphere through soil respiration is ten times greater than that resulting from the burning of fossil fuels [3]. Taking into account the considerable amounts of C stored in boreal soils [1] even small changes in soil respiration may cause great fluctuation in atmospheric CO_2 concentrations. Therefore, better understanding of soil respiration dynamics in diverse boreal forests is essential for understanding the global carbon balance [2].
The objectives of the present study are: (a) to study the dynamic changes in soil CO_2 efflux from the soil surface during frost-free season; (b) to identify the impact of meteorological variables (factors) on soil CO_2 efflux. The research was conducted in the boreal forests in Central Siberia (60°N, 90°E), Russia. Sample plots were represented by the lichen pine forest, moss pine forest, mixed forest and a plot with mineral sandy soil without a plant cover. We used the automated soil CO_2 flux system based on the infrared gas analyzer –LI-8100 (Li-cor Biogeosciences Inc., USA) for measuring the soil efflux. Soil temperature was measured next to each collar at the time of the CO2 efflux measurement with Soil Temperature Probe Type E (Omega, USA) in three depths –5, 10, 15 cm. Volumetric soil moisture was measured with Theta Probe Model ML2 (Delta T Devices Ltd., UK).
The presence and type of ground cover substantially affects the value of soil respiration fluxes. In 2015, the flow of carbon dioxide from the soil surface averaged 5.4 ±2.3 μmol CO_2 m^{-2} s^{-1}. The lowest soil respiration for forest areas was observed in the moss pine forest (1.14 μmol CO_2 m^{-2} s^{-1}). The lichen pine forest had the intermediate values (mean and SD) of soil respiration. A sandy soil plot without a plant cover demonstrated the lowest soil respiration (0.12 μmol CO_2 m^{-2} s^{-1}). The maximum soil respiration values and seasonal fluctuations were obtained in the mixed forest (29.62 μmol CO_2 m^{-2} s^{-1}).
The correlation analysis of dependence between soil temperature, soil moisture and soil CO_2 efflux showed that an increase of temperature and soil moisture at the beginning of the growing season (June) leads to inhibition of soil respiration processes. At the end of the growing season (September), we recorded a reduction in the impact of two climate factors (soil temperature and moisture) on soil respiration intensity. Nevertheless, the soil temperature appears to be the major driver controlling the soil CO_2 efflux during the frost-free season in analyzed Siberian boreal forests.
Literature:
1. Niinistö S. M., Kellomäki S., Silvola J. Seasonality in a boreal forest ecosystem affects the use of soil temperature and moisture as predictors of soil CO2 efflux. Biogeosciences, 8: 3169–3186. 2011.
2. Raich J.W., Potter C.S. Global patterns of carbon dioxide emissions from soils. Global Biogeochemical Cycles, 9: 23–36. 1995.
3. Sun L., Hu T., Kim J. H., Guo F., Song H., Lv X., Hu H. The effect of fire disturbance on short-term soil respiration in typical forest of Greater Xing'an Range, China. Journal of Forestry Research 25: 613-620. 2014.

4. Yuste J.C., Nagy M., Janssens I.A., Carrara A., Ceulemans R. Soil respiration in a mixed temperate forest and its contribution to total ecosystem respiration. Tree Physiol 25: 609–619. 2005.

Keywords: soil carbon efflux, boreal forest, Siberian forest, soil respiration, soil temperature, soil moisture

