The 10th Asia-Pacific GAW Workshop on Greenhouse Gases

October 25 (Mon.) – 26 (Tue.), 2021, Jeju, Republic of Korea

책임운영기관
National Institute of Meteorological Sciences

WORLD METEOROLOGICAL ORGANIZATION

GLOBAL ATMOSPHERE WATCH

PROGRAM

DATES (KST,UTC+9)		EVENT
Oct. 25 (Mon.)	14:30~14:40	**WELCOME SPEECH** ▪ Seong-Kyoun Kim (Director General of NIMS)
	14:40~14:45	Group Photo
	14:45~15:05	**KEYNOTE 1** ▪ Updates from the Global Atmosphere Watch Programme *Oksana Tarasova* *(Head of Atmospheric Environment Research Division, WMO)*
	15:05~15:45	**SESSION 1** **Inverse-modelling studies with GHGs monitoring data (I)** ▪ Introduction of the WMO endorsed IG³IS project INVERSE-KOREA *Sangwon Joo (KMA/NIMS)* ▪ High precision measurement of greenhouse gases and ozone depletion substances at background stations in China and national emission estimates *Bo Yao (CMA)* ▪ CarbonWatchNZ: Regional to National Scale Inverse Modelling of New Zealand's Carbon Balance *Beata Bukosa (NIWA)*
	15:45~16:00	Break time
	16:00~17:15	**SESSION 2** **Current issue and future plan regarding GHGs monitoring activities in Asia-Pacific regions (I)** ▪ Recent activities of World Data Centre for Greenhouse Gases (WDCGG) *Yousuke Sawa (JMA)* ▪ Measurement and Modeling of GHGs in India *Yogesh K. Tiwari (IITM)* ▪ JMA's activities for GHGs observation and recent topics *Shinya Takatsuji (JMA)* ▪ Inter-comparison activities for high quality atmospheric measurement *Soo Jeong Lee (KMA/NIMS)* ▪ Some initial assessment of greenhouse gas monitoring at Pha Din GAW station and development trend of climate change monitoring network in Vietnam *Tran Thi Thanh Hai (HYMOC)* ▪ Monitoring and Modeling of Carbon Cycle in East Asia for WMO IG³IS activity *Jinkyu Hong (Yonsei Univ.)*
	17:15~17:30	Break time
	17:30~18:10	**SESSION 3** **Advanced technologies for measuring GHGs with different platform (I)** ▪ Advancing the New Zealand atmospheric greenhouse gas observation network *Gordon W Brailsford (NIWA)* ▪ A Study of New Material-based Low-Cost and High-Precision Greenhouse Gas Monitoring Sensor *Young-Suk Oh (KMA/NIMS)* ▪ Calibration and uncertainty evaluation strategy for isotope ratio analysis of C, N and S in particulate matter *Jeong Sik Lim (KRISS)*

PROGRAM

DATES (KST,UTC+9)		EVENT
Oct. 26 (Tue.)	09:00~09:20	**KEYNOTE 2** ▪ IG³IS: An Integrated Global Greenhouse Gas Information System *Jocelyn Christine Turnbull (Radiocarbon Science Leader, CIRES)*
	09:20~10:00	**SESSION 4** **Advanced technologies for measuring GHGs with different platform (II)** ▪ Amazonia as a carbon source linked to deforestation and climate change *Luciana Vanni Gatti (INPE)* ▪ MethaneSAT: Towards detecting agricultural emissions from space *Sara Elisabeth Mikaloff-Fletcher (NIWA)* ▪ Aircraft observed horizontal and vertical distributions of CO_2, CH_4 and CO over Korea *Sunran Lee (KMA/NIMS)*
	10:00~10:15	Break time
	10:15~11:05	**SESSION 5** **Current issue and future plan regarding GHGs monitoring activities in Asia-Pacific regions (II)** ▪ Atmospheric methane 2020: misconceptions and opportunities *Youmi Oh (NOAA)* ▪ CSIRO Greenhouse Gas Measurement Activities *Zoë Miranda Loh (CSIRO)* ▪ The Greenhouse Gases Observation and Analysis at GAW station in Malaysia *Ahmad Fairudz Bin Jamaluddin (MET)* ▪ Interannual Variability of Atmospheric CH_4 and Its Driver Over South Korea Captured by Integrated Data in 2019 *Samuel Takele Kenea (KMA/NIMS)*
	11:05~11:20	Break time
	11:20~12:10	**SESSION 6** **Inverse-modelling studies with GHGs monitoring data (II)** ▪ Inverse modelling of CO_2, CH_4 and N_2O fluxes using MIROC4-ACTM and atmospheric data *Prabir Kumar Patra (JAMSTEC)* ▪ Inverse analysis with aircraft and ship observations for estimating CO_2 fluxes in Equatorial Asia *Yosuke Niwa (NIES)* ▪ Estimating regional emissions of synthetic greenhouse gases and ozone depleting substances based on atmospheric observations *Sunyoung Park (Kyungpook National Univ.)* ▪ Integrated GHG observations in Korea *Haeyoung Lee (KMA/NIMS)*
	12:10~12:20	Closing

KEYNOTE 1

Updates from the Global Atmosphere Watch Programme

O.Tarasova[1]

1. Atmospheric Environment Research Division, Science and Innovation Department, World Meteorological Organization

Abstract

In the presentation the recent updates from the GAW Programme will be presented. The particular focus will be on the area of greenhouse gas observations and utilization of such observations in support of mitigation services. The updates on the recently initiated and ongoing projects and future plans as well as on the recent publications will be presented.

KEYNOTE 2

IG^3IS: An Integrated Global Greenhouse Gas Information System

Jocelyn Turnbull[1,2*], Phil DeCola[3], Oksana Tarasova[4], Mario Peiro Espi[4] and the IG^3IS Steering Committee

1. GNS Science, New Zealand
2. CIRES, University of Colorado at Boulder, USA
3. Gist.earth, USA
4. WMO, Switzerland

Abstract

As the world moves to mitigate greenhouse gas emissions, timely, accurate emissions information is vital to track progress towards climate goals. The Integrated Global Greenhouse Gas Information System (IG^3IS) is a World Meteorological Organisation initiative that aims to expand the greenhouse gas observational capacity, extend it to regional and urban domains, and develop the information systems and modelling frameworks to provide greenhouse gas emissions information to society. IG^3IS has four objectives: (1) support inventory builders to reduce uncertainties in national inventory reports; (2) support cities and other sub-national entities to obtain actionable information on local emissions and source sectors; (3) provide information to industry and private business to help locate and quantify previously unknown emission sources; (4) support the global stocktake under the Paris Agreement.

IG^3IS views the science through the lens of stakeholder requirements, and success is measured by the extent to which greenhouse gas information is being used to support decisions. We will present examples of IG^3IS implementation through the development of Good Practice Guidelines, benchmarking of methodologies, and examples of IG^3IS endorsed research projects from around the world that are evaluating national and regional scale emissions and incorporating that information into emissions reporting frameworks.

Key Words: Greenhouse gas, emission reporting, climate science

Introduction of the WMO endorsed IG^{3}IS project INVERSE-KOREA

Sangwon Joo[1]*, Haeyoung Lee[1], Jinkyu Hong[2], Jeongsik Lim[3], Hochan Lee[4], Eunsook Kim[4] and Yeon-Hee Kim[1]

1. National institute of Meteorological Scieces/Korea Meteorological Administration
2. Yonsei University
3. Korea Research Institute of Standard and Service
4. Seoul Metropolitan Government Research Institute of Public Health and Environment

Abstract

As a part of the efforts for meeting the national greenhouse gas (GHG) emissions goal in South Korea, the National Institute of Meteorological Sciences/Korea Meteorological Administration (NIMS/KMA) launches a project named INVERSE-KOREA (INverse modeling for Validating and Evaluating of the Reduction of Sectoral greenhouse gas Emissions in KOREA) to monitor the GHG inventory in South Korea.

The project aims to develop a high-resolution (1~10km horizontal resolution) GHG inversion system for top-down GHG inventory estimates over South Korea based on a state-of-the-art NWP model and the GHG observation network to understand the sources and sinks of GHGs including CO_2, CH_4, and SF_6 in South Korea. The first phase takes 3 years from 2021 to 2023 and consists of 3 steps as follows: 1) Installing the inversions system, mainly the WRF-DART based system. 2) Testing and evaluating the installed inversion systems and compare with the bottom-up national inventory reports. 3) Starting the service of near-real-time top-down emission products for inventory communities and public.

We will frequently estimate the sectoral emissions changes in GHG to support the national GHG reduction policy for individual emission sectors in a timely manner. The topdown estimates to be established in this project can minimize the uncertainty in the national emission inventory for reliable verification of the Nationally Determined Contributions (NDC) that are critical in carrying out the policy for achieving carbon neutral by 2050.

The project is endorsed by WMO IG^{3}IS programme in this May and a general overview of the project will be introduced in this presentation.

Key Words: IG^{3}IS, greenhouse gas, INVERSE-KOREA, top-down, WRF-DART

High precision measurement of greenhouse gases and ozone depletion substances at background stations in China and national emission estimates

Bo Yao[1*], Miao Liang[1], Wanqi Sun[1], Shuangxi Fang[1,2] , Yi Liu[3], Xuekun Fang[4]

1. Meteorological Observation Center of China Meteorological Administration, Beijing, China
2. College of Environment, Zhejiang University of Technology, Hangzhou, China
3. Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
4. Center for Global Change Science, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States

Abstract

High precision measurement of greenhouse gases (GHGs) including CO_2, CH_4, N_2O, HFC, PFC, SF_6 and NF_3 as we all as ozone depletion substances (ODSs) including CFCs, HCFC, Halons, CCl_4, CH_3CCl_3 and CH_3Br were conducted at seven background stations of China Meteorological Administration (CMA) by the means of in-situ measurement and flask sampling. The mixing ratios of GHGs and ODSs were applied to estimate Chinese national emissions by inverse modeling. The results show Chinese land biosphere sink decreased significantly during 2010 to 2016 by using atmospheric mixing ratios of CO_2 from six CMA sites. Decreasing Chinese emissions were found for the first generation of ODS, such as CH_3CCl_3 as well as their substitutes HCFCs from 2011 to 2017. However, HFCs showed rapid growth trends due to their increasing productions and consumptions.

Key Words: greenhouse gases, ozone depletion substances, emission, background stations, inverse modeling

CarbonWatchNZ: Regional to National Scale Inverse Modelling of New Zealand's Carbon Balance

Beata Bukosa[1]*, Sara Mikaloff Fletcher[1], Gordon Brailsford[1], Peter Sperlich[1], Alex Geddes[1], Colin Nankivell[1], Dan Smale[1], Elizabeth Keller[2], Jocelyn Turnbull[2], Kay Steinkamp[1], Mike Harvey[1], Rowena Moss[1], Sally Gray[1], Stuart Moore[1], Sylvia Nichol[1], Tony Bromley[1] and Zoe Buxton[1]

1. NIWA, National Institute of Water and Atmospheric Research, New Zealand
2. GNS Science, Lower Hutt, New Zealand

Abstract

Atmospheric observations of CO_2 and other greenhouse gases have been widely used to constrain their flux estimates through atmospheric inverse modeling. Yet, applying these methods at national scale to verify and improve the National Inventory Report (NIR) and support the Paris agreement remains at the frontier of climate science.

We use inverse modelling to estimate New Zealand's carbon uptake and emissions (CO_2 and CH_4) using atmospheric measurements and model. This effort is part of a five year CarbonWatch-NZ research programme, which aims to develop a complete top-down picture of New Zealand's carbon balance using national inverse modelling and targeted studies of New Zealand's forest, grassland and urban environments. The work also focuses on identifying the prevailing processes driving CO_2 changes in New Zealand to support climate mitigation.

Our decade long (2011-2020) CO_2 inversion results show a stronger sink relative to the NIR, pointing to a strong CO_2 uptake in Fiordland, a region covered by indigenous temperate rainforest in New Zealand's South Island. Additional measurements collected in the Fiordland region (i.e., mixing ratios, CO_2 isotopes, carbonyl sulphide) also suggest a stronger CO_2 uptake, supporting our inversion results and suggesting that there might be something about this ecosystem that we do not yet understand. The CH_4 results from the inversion (covering years 2017-2020) align well with the prior information and our current knowledge about CH_4 emissions in New Zealand, replicating the seasonal cycle without any prior knowledge of it.

Key Words: carbon cycle, National scale budget, inversion, forest

Recent activities of World Data Centre for Greenhouse Gases (WDCGG)

SAWA Yousuke[1*]
KINOSHITA Atsuya[1], OHKUBO Saki[1], OWAKI Mika[1],
NAGAI Yasuyuki[1], OGI Akinori[1], TONOZAKI Hiroki[1]

1. Atmospheric Environment and Ocean Division, Atmosphere and Ocean Department, Japan Meteorological Agency (JMA)

Abstract

The World Data Centre for Greenhouse Gases (WDCGG) is one of the World Data Centres (WDCs) under the Global Atmosphere Watch (GAW) programme, which has been operating at the Japan Meteorological Agency (JMA) since 1990. The function of the WDCGG is to gather, archive and provide data on greenhouse gases (CO_2, CH_4, CFCs, N_2O, etc.) and related gases (CO, H_2, etc.).
We updated WDCGG website (https://gaw.kishou.go.jp/) in August 2018 to respond to the changing needs of users/contributors such as detailed metadata, improved findability and selection of the data, improved submission process, download information. The WDCGG has also started providing NetCDF format data files and issuance of Digital Object Identifiers (DOIs) in March 2021. The number of reporting stations and submitted gas species has significantly increased during WDCGG's 30-year activity period. In addition to the increasing data from surface-based stations, ships and aircraft, satellite CO_2 datasets became available on the WDCGG website for GOSAT in March 2019 and for OCO-2 in March 2020, respectively. We hope these improvements at the WDCGG would promote the wider use of the data and would facilitate long-term monitoring of global distribution of greenhouse gases.
The data submitted to the WDCGG are used for global analysis in the WMO Greenhouse Gas Bulletin, which is usually published before the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). Detailed data and analyses are also provided in WMO WDCGG Data Summary. Analyzed global annual mean mixing ratios for CO_2, CH_4 and N_2O were referred as values of WMO/GAW in chapter 2 of the IPCC AR6-WGI. We believe that these publications/activities would support continuous development in the observational and research activities about greenhouse gases.
We would like to thank for strong contributions to the activities of the WDCGG from all the users, data providers and experts in the GAW community. Your continuing support is really appreciated.

Key Words: greenhouse gases, data centre

Measurement and Modeling of GHGs in India

Yogesh K. Tiwari[1*], Santanu Halder[1], Pramit Kumar Deb Burman[1], Smrati Gupta[1],

1. Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India

Abstract

Despite the global efforts to curb the menace of increasing anthropogenic greenhouse gases (GHG) emissions, observed atmospheric GHG concentrations have broken all the records and reported the highest ever values in the recent past. Some of these emissions get compensated by vegetation uptake. Quantifying the carbon balance between the emissions of industry and transport and the ecosystem uptake in India is an important step towards designing effective greenhouse gas mitigation strategies in this subcontinent. The only land station for greenhouse gases (GHG) monitoring in India is Cape Rama (CRI) Goa, which operated for more than ten years and was discontinued in 2012. There was no GHG monitoring in India other than CRI. LSCE France, in collaboration with CMMACS and IIA Bangalore, started few monitoring sites in 2007, which were mainly centered over the far eastern island, east coast, or extreme northern part of India.

IITM has already initiated various Greenhouse gases/carbon flux monitoring and modeling projects in India to fill the gap. We established a Gas Chromatograph (GC) lab at the IITM Pune in 2009. We started the first surface site at Sinhagad (SNG) Pune in November 2009 where we collect glass flask sample on a weekly interval and analyze at the GC lab. SNG is currently the only operational GHG monitoring site in western India. We use WMO accorded standards to calibrate all these observations. GC lab is part of an inter-calibration program among the WMO/GAW laboratories in Asia (JMA, KMA, etc.).

For upper atmospheric GHGs monitoring, we used airplane campaigns during 2014, 2015, 2018 (under the CAIPEEX airplane campaign project), where we monitored horizontal and vertical profiles GHGs in different parts of India. We have initiated a GHG transport modeling framework at the IITM Pune, developing a global and high-resolution modeling approach to estimate GHGs sources and sink over the Indian sub-continent and adjoining regions. A tall tower project at the Atmospheric Research Testbed (ART) in central India (the outskirts of Bhopal) will significantly help in constraining the Indian emissions.

This study will present GHG observation and modeling outputs and discuss transport processes and emissions variability in India.

Key Words: greenhouse gases; observations; model simulations; emissions and variability

JMA's activities for GHGs observation and recent topics

*TAKATSUJI Shinya[1], KINOSHITA Atsuya[1], SAITO Atsushi[1], SAITO Kazuyuki[1], KAMEOKA Yoshihumi[1], KODA Haruka[1], YUKITA Kazuya[1], YOSHIDA Masashi[1], SATO Shohei[1], IKEDA Ryo[1], FUJIWARA Subaru[1], IWAKI Masashi[1], SAWA Yousuke[1], TSUBOI Kazuhiro[2] and ISHIJIMA Kentaro[2]

1. Japan Meteorological Agency (JMA), Tokyo, Japan
2. Meteorological Research Institute (MRI), Tsukuba, Japan

Abstract

The Japan Meteorological Agency (JMA) has been observing greenhouse gases (GHGs) at three ground stations and by using an aircraft and observation vessels, and serves as the World Calibration Centre (WCC) for methane (CH_4) in Asia and the South-West Pacific within the framework of the Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO). In this 10th Asia-Pacific GAW Workshop on Greenhouse Gases, we introduce JMA's new activities for GHGs observation and recent topics.

In 2020, JMA started the observation of the Hydrofluorocarbons (HFCs), which are known as potent greenhouse gases, at the Minamitorishima GAW Global Station as it relates to the Kigali amendment to Montreal protocol that restricts the production and emission of HFCs. The data is available from WMO/GAW World Data Centre for Greenhouse Gases (WDCGG). https://gaw.kishou.go.jp

The WCC-JMA has so far carried out five rounds of inter-comparison experiments of CH_4 reference gases from 2001 to 2019 as well as ongoing sixth and seventh rounds as one of the WCC activities in co-operation with NOAA/ESRL (WMO/CCL, USA), CSIRO (Australia), NIWA (New Zealand), CMA (China), KMA/NIMS, KRISS (Republic of Korea), IITM (India), and several Japanese laboratories. The purpose of the inter-comparisons is to understand the differences between the participants' CH_4 standard scales as well as to monitor the long-term stability of standard gases in Asia and the South-West Pacific regions. The results of fifth in Japan and sixth in Asia were issued as GAW reports (GAW Report 263 and 264, respectively) in the WMO Library.

Key Words: GHGs, WCC, HFCs, Inter-comparison experiments, GAW report

Inter-comparison activities for high quality atmospheric measurement

Soo Jeong Lee[1*] and Haeyoung Lee[1]

1. Innovative Meteorological Research Department, Korea Meteorological Administration/ National Institute of Meteorological Sciences

Abstract

Under the Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO), the monitoring stations in the network have been producing atmospheric measurement data on a common calibration scale. To prevent the possible bias from the error among measurement data, the compatibility goal was set within the WMO/GAW network. Inter-comparison experiment is the typical way of verifying compatibility among laboratories within the network. As National Institute of Meteorological Sciences (NIMS) of Korea Meteorological Administration (KMA) has taken the role of World Calibration Center of SF_6 (WCC-SF_6) since 2012, it implemented the SF_6 Inter-comparison experiment (SICE) to supervise the quality of the measurement data among 11 laboratories from 7 countries from 2016 to 2017. As a result, 75% of the laboratories were within the WMO/GAW compatibility goal (±0.02 ppt) in high and low levels. And, it shows the importance of using the single standard scale in the network for data management. As the same concept applied to domestic GHGs network of Republic of Korea, inter-comparison experiments within the network were conducted in 2016 and 2020, respectively. According to the domestic inter-comparison experiments, the recent advanced instruments (such as a cavity ring down spectroscopy) affect the quality of the measurement data, and to develop and apply the proper calibration method is necessary for each instrument and measurement condition. Also, repeatability, reproducibility, and linearity checkups before the operation of the instruments are indispensable. In short, inter-comparison activities of global and domestic facilitate the improvement on the quality of the data by examining the current situation within the network.

Key Words: Inter-comparison experiment, GHGs, Measurement quality management, WMO/GAW

Some initial assessment of greenhouse gas monitoring at Pha Din GAW station and development trend of climate change monitoring network in Vietnam

Tran Thi Thanh Hai[1*], Martin Steinbacher[2]

1. Hydro-Meteorological Observation Center (HYMOC), Viet Nam Meteorological and Hydrological Administration (VNMHA), Ministry of Natural Resources and Environment of Viet Nam (MONRE), Viet Nam
2. Swiss Federal Laboratories for Materials Science and Technology (Empa), Switzerland

Abstract

Pha Din Global Atmosphere Watch (GAW) station is funded by the Swiss Government on the basis of cooperation between the Viet Nam Meteorological and Hydrological Administration and the Federal Office of Meteorology and Climatology MeteoSwiss. This is considered the first official greenhouse gas monitoring station in Vietnam. The station started operation in 2014 with monitoring parameters of greenhouse gases CO_2, CO, CH_4, O_3 and Aerosols. Since then, the station has maintained relatively stable operation and has provided annual data to the World Data Centre for Greenhouse Gases (WDCGG) and the World Data Centre on Reactive Gases at (WDCRG).) to serve and share effectively in the assessment of global climate change and the research of scientists in the community. However, during the operation of Pha Din station, there have been some equipment problems and the other troubles that need to be fixed.

Apart from Pha Din GAW station, in the Planning of Vietnam's National Environmental and Natural resources Monitoring Network to 2030, a system of 35 climate change monitoring stations (reference meteorology) will also be developed, in which monitoring greenhouse gas parameters are similar to Pha Din station. The objective of this system is to gradually strengthen the capacity of the monitoring network, serving forecasting, warning, prevention and mitigation of damage caused by natural disasters and response to climate change in Vietnam. In 2021, 7 of the above 35 stations have been invested in greenhouse gas monitoring equipment.

This presentation will focus on evaluating the operation of the Pha Din GAW station in the past time and the development trend of the climate change monitoring network in Vietnam in the coming time.

Monitoring and Modeling of Carbon Cycle in East Asia for the WMO IG^{3}IS activity

J. Hong[1*], W. Cho[1], J. Kim[1], G. Gim[1], A. Yoon[1], J. Lee[1], S. Jo[1],
E. Saikawa[2], A. Avramov[2], C. Shim[3], H. Lee[4], S. Joo[4]

1. Department of Atmospheric Sciences, Yonsei University, Korea
2. Department of Environmental Sciences, Emory University, USA
3. Korea Environment Institute, Korea
4. National Institute of Meteorological Sciences, Korea

Abstract

Greenhouse gases inversion system provides useful information to private sectors and policy makers for their efforts to reduce carbon emission into the atmosphere. Particularly, East Asia contributes to substantial global greenhouse gas emission and megacities have been emerged with rapid urbanization and economic growth. Climatologically, the Asian monsoon plays an important role in carbon cycle in this region. Recently, consortium of several institutes launched the project for the development of greenhouse gases inversion system to monitor spatiotemporal variations of greenhouse gases in East Asia as one of the WMO IG^{3}IS activities. In this presentation, we present surface CO_2 budget based on the eddy covariance methods over various land covers in across the urbanization gradient in Korea and introduces the development of the greenhouse gas emission monitoring system

Key Words: WMO IG^{3}IS, East Asia, urbanization, surface CO_2 budget, greenhouse gases inversion system

Advancing the New Zealand atmospheric greenhouse gas observation network

Gordon Brailsford[1*], Mark Murphy[1], Sylvia Nichol[1], Tony Bromley[1], Lucas Gatti Domingues[2], Sally Gray[1], John McGregor[1], Sara Mikaloff Fletcher[1], Rowena Moss[1], Rahul Peethambaran[1], Peter Sperlich[1], Kararaina Te Puni[1], Jocelyn Turnbull[2]

1. NIWA, National Institute of Water and Atmospheric Research, New Zealand
2. GNS Science, Lower Hutt, New Zealand

Abstract

The greenhouse gas observation network in New Zealand was initially developed to observe baseline air arriving off the ocean that was representative of large areas of the mid-latitude southern hemisphere. In more recent years the focus has shifted to include observations of air that has interacted across the country. This has allowed us to utilize inverse modelling techniques at a national scale for both carbon dioxide and methane to identify sources and sinks of these species.

To provide a better national coverage and to allow for specific sectors to be studied more closely an expanded network has been developed that provides observation in key areas. Specific requirements for gas species, study environment and power supply are identified for each site and an in situ analyser is selected that are most appropriate for the site. A standardised format for control and data management improves the network management.

Supporting the in situ observations we utilise a number of tracer species that assist in interpreting the processes involved in production and removal of greenhouse gases. Tracer techniques can provide insight into fossil fuel contributions, chemistry and the role of photosynthesis. The network flask collections provide air for laboratory studies of isotopic composition, and related species like carbonyl sulphide that are unable to be performed in the field.

Key Words: network observation, carbon dioxide, methane, carbonyl sulphide

A Study of New Material based Low-Cost and High-Precision Greenhouse Gas Monitoring Sensor

Young-Suk Oh[1*], Su-Ryon Shin[2], Hyunyoung Jung[3], Chang-Kee Lee[4], Sangwon Joo[1], Haeyoung Lee[1], Chu-Yong Chung[1] and Yoen-Hee Kim[1]

1. National Institute of Meteorological Sciences, Innovative Meteorological Research Department, 33, Seohobuk-ro, Seogwipo-si, Jeju-do, 63568, Korea
2. Harvard Medical School, Division of Engineering in Medicine, Brigham and Women's Hospital 65 Landsdowne Street, Rm. 281, Cambridge, MA 02139
3. Department of Energy Engineering, Gyeongsang National University, Jinju-Si, Gyeongnam 52725, Korea
4. Korea Institute of Industrial Technology, Korea Packaging Center, IT301-203, Bucheon Techno Park, Ssangyoung 3 Cha. 397, Seokcheon-ro, Bucheon-si, Gyeonggi-do, 14449, Korea

Abstract

Carbon dioxide (CO_2) is the most important greenhouse gas associated with human activities and the second most important gas in global warming after steam. The World Meteorological Organization (WMO), in its annual bulletin on the impact of greenhouse gases, lays out that the increment of this gas is caused by changes in the combustion of land-based fossil fuels, and cement production.

The main purpose of this study is to develop a Low-Cost (LC) and High-Precision (HP) Greenhouse Gas (GHG) monitoring sensor that can measure the total carbon column of the GHG concentration in the atmosphere by using the novel material. Secondarily, it has the purposes of establishing a high density GHG monitoring network and supporting the scientific monitoring of GHG concentration in a city. The LC and HP greenhouse gas sensor material will be a graphene based 3D structure. Graphene based 3D materials emerged as promising candidates for a vast range of photonic and optoelectronic applications with high light absorption capability such as photo detection. There is a growing interest toward graphene base 3D materials due to their exceptional geometrical and electronic features, which make them unique for photonic and optoelectronic applications. The graphene absorption peaks were obtained between 1000 nm and 4500 nm while GHG absorption regions are from 1580 to 1650nm for CO_2, from 1630 to 1690nm for CH_4 and from 2780 to 3030nm for SF_6, respectively. In addition, the quantum efficiency value is 0.8. Our results disclose exciting possibilities for infrared optical light-absorbing devices on graphene based 3D materials.

Key Words: Low-Cost, High-Precision, GHG, Graphene based 3D Structure, Photonic, Infrared

Calibration and uncertainty evaluation strategy for isotope ratio analysis of C, N and S in particulate matter

Yongmok Kwon[1,2], Yonghyun Lim[3], Jeongsoon Lee[1,2], and Jeong Sik Lim[1,2*]

1. Greenhouse gas metrology team, Korea Research Institute of Standards and Science (KRISS), Gajeong-ro 267, Yuseong-gu, Daejeon, 34113, Republic of Korea
2. Science of Measurement, University of Science and Technology (UST), Gajeong-ro 217, Yuseong-gu, Daejeon, 34113, Republic of Korea
3. Metrology of inorganic analysis, Korea Research Institute of Standards and Science (KRISS), Gajeong-ro 267, Yuseong-gu, Daejeon, 34113, Republic of Korea

Abstract

We measured the stable isotope ratio of major elements of carbon, nitrogen, and sulfur (CNS) in particulate matter (PM) using the Elemental Analyser–Isotope Ratio Mass Spectrometry (EA-IRMS). PM was sampled in a tin cup to be oxidatively combusted in a copper reactor which was in oxygen atmosphere, to yield CO_2 and SO_2. For the nitrogen, N2 was formed by reductive reaction. Because mixing ratios of the CNS elements varies in each PM sample, dynamic dilution of combusted gases are required for avoiding saturation or bias in the measured signal. Linearity in a response of isotope ratio (IR) needs to be carefully tested in the near future. In this presentation, dilution ratio was fixed to a certain value. In order to simultaneously measure IR of CNS, a jump between configurations of the ion optics and Faraday cups for δC, δN and δS was conducted. Calibration standard was used in mixed form of USGS reference material (RM) for CN and IAEA RM for S. Because of limitation in resolving power of the column (Porapak-Q), chromatographic conditions were carefully adjusted to have best repeatability in the IR measurement. For evaluation of the calibration uncertainty, excel file for the ordinary least squares method was used to propagate measurement uncertainty into the calibrated value. In addition, explicit formulae were given to give statistical insight regarding the calibration.

Amazonia as a carbon source linked to deforestation and climate change

Luciana V. Gatti*[1], Luana S. Basso[1], John B. Miller[2], Manuel Gloor[3], Lucas Gatti Domingues[1,4], Henrique L. G. Cassol[1], Graciela Tejada[1], Luiz E. O. C. Aragão[1], Carlos Nobre[5], Wouter Peters[6], Luciano Marani[1], Egidio Arai[1], Alber H. Sanches[1], Sergio M. Corrêa[1,7], Liana Anderson[8], Celso Von Randow[1], Caio S. C. Correia[1], Stephane P. Crispim[1] & Raiane A. L. Neves[1]

*[1]Earth Science General Coordination, INPE; [2]IPEN; [3]GMD/ESRL/NOAA; [4]University of Leeds; [5]IEA/USP; [6]Wageningen University; [7]UERJ; [8]CEMADEM

Abstract

Amazonia hosts the Earth's largest tropical forests and has been shown to be an important carbon sink over recent decade. This carbon sink seems to be in decline, however, as a result of factors such as deforestation and climate change. Here we investigate Amazonia's carbon budget and the main drivers responsible for its change into a carbon sourceWe performed 590 aircraft vertical profiling measurements of lower-tropospheric concentrations of carbon dioxide and carbon monoxide at four sites in Amazonia from 2010 to 2018. We find that total carbon emissions are greater in eastern Amazonia than in the western part, mostly as a result of spatial differences in carbon-monoxide-derived fire emissions. Southeastern Amazonia, in particular, acts as a net carbon source (total carbon flux minus fire emissions) to the atmosphere. Over the past 40 years, eastern Amazonia has been subjected to more deforestation, warming and moisture stress than the western part, especially during the dry season, with the southeast experiencing the strongest trends. We explore the effect of climate change and deforestation trends on carbon emissions at our study sites, and find that the intensification of the dry season and an increase in deforestation seem to promote ecosystem stress, increase in fire occurrence, and higher carbon emissions in the eastern Amazon. This is in line with recent studies that indicate an increase in tree mortality and a reduction in photosynthesis as a result of climatic changes across Amazonia.

Reference: Gatti et al., 2021 Nature, https://doi.org/10.1038/s41586-021-03629-6

Key Words: Amazonia, Carbon flux, Carbon budget, climate change, deforestation

MethaneSAT: Towards detecting agricultural emissions from space

Sara Mikaloff-Fletcher[1], Anne-Gaelle Ausseil[2], Gordon Brailsford[1], Beata Bukosa[1], Joshua Benmergui[3], David Campbell[4], Jonathan Franklin[3], Alex Geddes[1], Jordan Goodrich[4], Steven P. Hamburg[5], Darren Ngaru King[1], Richard Law[2], Johannes Laubach[2], David Noone[6], David Pollard[1], Jocelyn Turnbull[7], Hinrich Schaefer[1], Louis Schipper[4], Dan Smale[1], Steve Wofsy[3]

1. NIWA
2. Manaaki Whenua Landcare Research
3. Harvard University
4. University of Waikato
5. MethaneSAT LLC/EDF
6. University of Auckland
7. GNS Science

Abstract

The MethaneSAT satellite, scheduled for launch in fall 2022, is a joint American and Aotearoa-New Zealand (Aotearoa-NZ) initiative, involving a partnership between Environmental Defense Fund's(EDF) subsidiary MethaneSAT LLC, and the New Zealand government. The satellite's core mission is to catalyze CH_4 emission reductions around the world by measuring atmospheric CH_4 with unprecedented precision and mapping flux rates. While MethaneSAT was designed to detect emissions from oil and gas infrastructure, we hypothesize that it can also be used to measure more diffuse and thus harder to resolve agricultural methane emissions. We present plans for a research programme to develop and test this capability.

Aotearoa-NZ is the ideal natural laboratory for this research due to its distance from other land areas, its greenhouse gas measurement and modelling capability and its unusual greenhouse gas emission profile. CH_4 emissions make up nearly half of its gross emissions budget, and 85% of these emissions are from agriculture. Atmospheric inverse modelling will leverage meteorology from Aotearoa-NZ's 1.5km resolution numerical weather prediction model and inverse modelling tools being used by the MethaneSAT team. Aotearoa-NZ's long-running TCCON site at Lauder will be supplemented by observations from two EM27 instruments and aircraft-based vertical profile data.

We will develop a global observation strategy to target agricultural emissions from ruminant animals and rice agriculture. We will also identify a list of priority targets where MethaneSAT has the potential to provide valuable new emission information. Then, we will work with policy and advocacy experts to identify priority targets where mitigation solutions are practical. Thus, our strategy will consider not only where MethaneSAT can quantify emissions with the most accuracy but also where such data will be most beneficial for realizing emission reductions.

Key Words: Agricultural greenhouse gas emissions, methane, remote sensing

Aircraft observed horizontal and vertical distributions of CO_2, CH_4 and CO over Korea

Sunran Lee*, Haeyoung Lee, Samuel Takele Kenea, Sangwon Joo, Chu-Yong Chung, Yeon-Hee Kim

Innovative Meteorological Research Department, National Institute of Meteorological Sciences (NIMS), 33 seohobuk-ro, Seogwipo-si 63568, Jeju Island, South Korea.

Abstract

A new Korean Meteorological Administration (KMA) research aircraft measurement platform has been established for regular observations for scientific purpose over South Korea since 2018. CRDS G-2401m analyzer mounted on the King Air 350HW was used to continuous measurement of CO_2, CH_4 and CO mole fraction. There are several regular aircraft scientific campaigns were conducted over Republic of Korea (hereafter Korea) to collect the in-situ greenhouse gases: First, vertical profile (0.5-9 km) measurements at a regional Global Atmosphere Watch (GAW) Anmyeon-do (AMY) background station, it could be used to verify Satellite retrievals and model simulations (The Climate change Monitoring: The CM01 mission). Second, a within-boundary layer survey over the western Korean inland for identifying the CO_2, CH_4, and CO emission hot-spots for each season (The Climate change Monitoring: The CM02 mission); Third, a multi-altitude (0.3-5 km) survey over the Yellow Sea for monitoring the pollutant plumes transported into Korea from China through Yellow Sea (The Environment Monitoring: The EM mission). Hence, the aircraft observations can map the spatio-temporal variations of CO_2, CH_4 and CO over Korea and provide useful high-density dataset to better understand emissions source characteristics in Korea and their trans-boundary transport mechanism across the Yellow Sea. Also, we analyzed the characteristics of vertical distributions to identify emissions sources for pollution plume observed on surface and in free troposphere, combination of back-trajectory analysis, taking account of convective mixing, and satellite data. Overall, the King Air 350 aircraft observation platform can provide useful high-density data for better understanding the effects of the CO_2 and CH_4 emissions sources in East Asia and their long-range transport mechanism through surface to free troposphere, and critical information for decision makers in developing the plans to reduce the anthropogenic emissions of greenhouse gases in the region.

Key Words: Aircraft, CO_2, CH_4, CO, Vertical profile, Horizontal profiles, South Korea

Acknowledgement: This research was funded by the Korea Meteorological Administration Research and development Program "Development of application technology on atmospheric research aircraft" under grant (KMA2018-00222).

Atmospheric methane 2020: misconceptions and opportunities

Youmi Oh[1,2], Lori Bruhwiler[1,*], Roisin Commane[3], Merritt Turetsky[4], Sylvia Michel[4], and Ruth Varner[5]

1. Global Monitoring Laboratory, NOAA, Boulder, CO, USA.
2. Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO, USA.
3. Department of Earth & Environmental Sciences, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA.
4. Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO, USA.
5. Department of Earth Sciences and Earth Systems Research Center, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH, 03824, USA.

Abstract

Atmospheric methane (CH_4) grew at the fastest rate ever recorded in 2020. The recent acceleration in atmospheric CH_4 growth is a challenge for reaching the climate goals of the Paris Agreement, which requires steep cuts in the atmospheric CH_4 emissions. A recent UNEP report proposes that feasible mitigation approaches could reduce anthropogenic emission by 45%, avoiding 0.3 ºC of warming by mid-century. However, care must be taken when basing climate policy on our imperfect ability to interpret limited long-term observations of atmospheric CH_4 as we still lack an understanding of processes governing sources and sinks.

Observations show that, as CH_4 has increased since 2007, δ13C(CH_4) has shifted to more negative values, after increasing for the last 200 years. This suggests that the recent growth is primarily due to microbial sources. This contradicts the media's attention on fossil emission increase. Studies have proposed that U.S. fossil emissions are the dominant cause of the global growth of post-2006 atmospheric CH_4. However, atmospheric simulations with a comprehensive CH_4 isotope source signature inventory do not support the theory that leaking oil and gas infrastructure alone could explain the recent growth of atmospheric CH_4.

A rapid warming in the Arctic plus a greater understanding of the global significance of permafrost carbon storage and emissions has also led to media focus on the Arctic region, with headlines such as "Arctic methane bombs" and "Arctic Emergency". While there is ample evidence of potentially large CH_4 emissions from high northern latitude wetlands and aquatic ecosystems, there is also recognition that field monitoring of CH_4 emissions may oversample poorly drained CH_4-producing systems and under-sample drier locations associated with CH_4 uptake. Atmospheric inversion models based on observations of CH_4 in the atmosphere are also not suggesting large changes in the net CH_4 flux north of 50° N.

The current global network of CH_4 observations is insufficient to conclusively identify the source of the 2020 CH_4 increase. As climate mitigation strategies are enacted, it will be difficult for the existing observation networks to monitor reductions in anthropogenic CH_4. More comprehensive measurements are needed to disentangle natural and anthropogenic microbial emissions and to detect and understand feedbacks between natural sources and climate change.

Key Words: global methane 2020, fossil emission, Arctic permafrost methane emission, measurements.

CSIRO Greenhouse Gas Measurement Activities

Zoë Loh[1*], Ray Langenfelds[1], Elise-Andrée Guérette[1], Blagoj Mitrevski[1], Darren Spencer[1], David Thornton[1], Ann Stavert[1], Chris Roulston[1], Paul Krummel[1]

1. CSIRO Oceans and Atmosphere, Aspendale, Victoria, Australia

Abstract

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's National Science Agency and operates a global flask network for background greenhouse gas (GHG) observations with a strong Southern Hemisphere focus. In addition, we operate an in-situ monitoring network for CO_2 and CH_4, focused on Australia and its Antarctic Territories, including on the Research Vessel *Investigator*.

In this presentation, we will describe key developments in the Global Atmospheric Sampling LABoratory (GASLAB). We will highlight technology advances in GASLAB, that have extended our capacity to make in-situ H_2 measurements and will allow us to add SF_6 to our standard suite of trace gases measured through the flask network.

We will describe our collaborations with local First Nations (Larrakia) Rangers in Northern Australia, to support our tropical observatory, Gunn Point. Finally, we will describe our work building towards better urban GHG emissions monitoring in Australia.

Key Words: greenhouse gas measurement networks

The Greenhouse Gases Observation and Analysis at GAW station in Malaysia

Jamaluddin, A.F[1], Sammathuria, M.K[1], Jahaya, M.F[1]

1. Atmospheric Science and Cloud Seeding Division, Malaysian Meteorological Department, Malaysia

Abstract

In the presentation the recent updates from the Lembah Danum, Sabah (GAW station) will be presented. The particular focus will be on the seasonal variation of greenhouse gas observations and utilization of such observations in support to changing climate over Malaysia. The updates on ongoing projects and future plans will also be presented.

Interannual Variability of Atmospheric CH_4 and Its Driver Over South Korea Captured by Integrated Data in 2019

Samuel Takele Kenea[1,*], Haeyoung Lee[1], Sangwon Joo[1], Shanlan Li[1], Lev D. Labzovskii[2], Chu-Yong Chung[1] and Yeon-Hee Kim[1]

1. Innovative Meteorological Research Department, National Institute of Meteorological Sciences (NIMS), 33, Seohobuk-ro, Seogwipo-si, Jeju-do 63568, Korea
2. R&D Satellite and Observations Group, Royal Netherlands Meteorological Institute (KNMI), 3731GA De Bilt, The Netherlands

Abstract

Understanding the temporal variability of atmospheric methane (CH_4) and its potential drivers can advance the progress toward mitigating changes to the climate. To comprehend interannual variability and spatial characteristics of anomalous CH_4 mole fractions and its drivers, we used integrated data from different platforms such as in situ measurements and satellites (TROPOspheric Monitoring Instrument (TROPOMI) and Greenhouse Gases Observing SATellite (GOSAT)) retrievals. A pronounced change of annual growth rate was detected at Anmyeondo (AMY), Republic of Korea, ranging from −16.8 to 31.3 ppb yr^{-1} as captured in situ through 2015–2020 and 3.9 to 16.4 ppb yr^{-1} detected by GOSAT through 2014–2019, respectively. High growth rates were discerned in 2016 (31.3 ppb yr^{-1} and 13.4 ppb yr^{-1} from in situ and GOSAT, respectively) and 2019 (27.4 ppb yr^{-1} and 16.4 ppb yr^{-1} from in situ and GOSAT, respectively). The high growth in 2016 was essentially explained by the strong El Niño event in 2015–2016, whereas the large growth rate in 2019 was not related to ENSO. We suggest that the growth rate that appeared in 2019 was related to soil temperature according to the Noah Land Surface Model. The stable isotopic composition of $^{13}C/^{12}C$ in CH_4 (δ^{13}-CH_4) collected by flask-air sampling at AMY during 2014–2019 supported the soil methane hypothesis. The intercept of the Keeling plot for summer and autumn were found to be −53.3‰ and −52.9‰, respectively, which suggested isotopic signature of biogenic emissions. The isotopic values in 2019 exhibited the strongest depletion compared to other periods, which suggests even a stronger biogenic signal. Such changes in the biogenic signal were affected by the variations of soil temperature and soil moisture. We looked more closely at the variability of XCH_4 and the relationship with soil properties. The result indicated a spatial distribution of interannual variability, as well as the captured elevated anomaly over the southwest of the domain in autumn 2019, up to 70 ppb, which was largely explained by the combined effect of soil temperature and soil moisture changes, indicating a pixel-wise correlation of XCH_4 anomaly with those parameters in the range of 0.5–0.8 with a statistical significance ($p < 0.05$). This implies that the soil-associated drivers are able to exert a large-scale influence on the regional distribution of CH_4 in Korea.

Key Words: in situ; TROPOMI; GOSAT; CH_4; δ^{13}-CH_4

Inverse modelling of CO_2, CH_4 and N_2O fluxes using MIROC4-ACTM and atmospheric data

Prabir K. Patra[1,2*]

1. Research Institute for Global Change, JAMSTEC, Yokohama, 236-0001, Japan
2. Center for Environmental Remote Sensing, Chiba University, Chiba, Japan

Abstract

Greenhouse gases, e.g., carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), are the main cause of global warming in the period 1850-1900 to 2010-2019, as per the recently approved 6th assessment report of the IPCC working group I in August 2021. The nationally determined contributions (NDCs) are all set for discussion/negotiation at the upcoming Conference of the Parties (COP-26) in November 2021 towards drastic reduction of emissions all the 3 species, with an emphasis on the CO_2 emissions. We take advantage of the long-term measurements and use atmospheric chemistry-transport models (ACTMs) for estimations of regional sources and sinks by inverse (top-down) modelling. Our model heavily relies on the a priori source and sinks inventories that are constructed using industrial activity data and biogeochemical models in a Bayesian inversion framework.

At JAMSTEC, we use the ACTM based on Model for Interdisciplinary Research on Climate, version 4.0 (MIROC4-ACTM) and estimated optimised sources and sinks at 84 (53 for CH_4) partitions of the globe at monthly-mean time intervals. The results contribute to budget releases of Global Carbon Project, IPCC AR6, EU's VERIFY etc. Figure below shows the regional net fluxes for CO_2, CH_4 and N_2O averaged over the period 2007-2016. Accurate estimation of sources and sinks at regional scale, and robust assessment of their uncertainties based on multiple lines of evidence is key for reducing emissions for most effective policymaking toward meeting the temperature target set by the Paris Agreement.

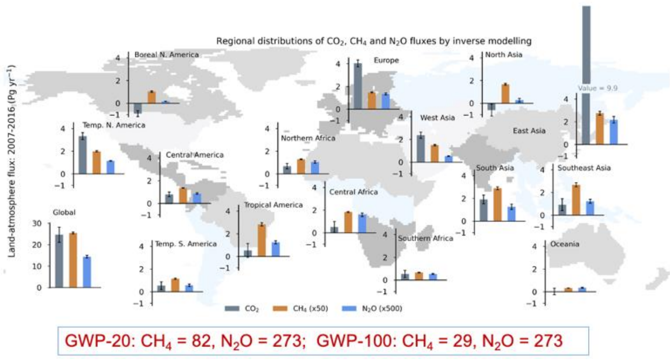

Figure : Regional distributions of net fluxes (emission – sink) of CO_2, CH_4 and N_2O. The global warming potentials of CH_4 and N_2O (text in red) are in the similar order magnitude as the scaling factors (legends), which could be used for conversion to CO_2-equivalent emissions. (Plot adapted from IPCC AR6, Chapter 5)

Key Words: Greenhouse gases; inverse modelling; chemical transport model

Inverse analysis with aircraft and ship observations for estimating CO_2 fluxes in Equatorial Asia

Yosuke Niwa[1,2*], Yousuke Sawa[2,a], Hideki Nara[1], Toshinobu Machida[1], Hidekazu Matsueda[2,b], Taku Umezawa[1], Akihiko Ito[1], Shin-Ichiro Nakaoka[1], Hiroshi Tanimoto[1], and Yasunori Tohjima[1]

1. National Institute for Environmental Studies, Tsukuba, Japan
2. Meteorological Research Institute, Tsukuba, Japan
   [a]now at: Japan Meteorological Agency, Tokyo, Japan
   [b]now at: Dokkyo University, Soka, Japan

Abstract

Inverse analysis is a powerful tool for quantitatively estimating spatiotemporal variations of surface CO_2 fluxes. Conventionally, a global inverse analysis of atmospheric CO_2 uses ground-based observations, in which mobile platform, such as aircraft, observations are used for evaluation of estimated fluxes as independent data of the inversion. However, such mobile observations could constrain flux estimation especially where ground-based observations are sparse. In fact, a previous inversion study that extensively used observations from the CONTRAIL project demonstrated that observations even in the upper-troposphere could effectively constrain tropical flux estimation through active vertical transport. In the CONTRAIL project, in-situ measurements onboard commercial airliners are used to observe three-dimensional distributions of atmospheric CO_2 with a high frequency, which constructs a unique observational network in the world. In this study, an inversion analysis aiming at biomass burning emissions from Equatorial Asia for 2015 was performed with the CONTRAIL CO_2 data and also with shipboard observations from the National Institute for Environmental Studies (NIES) Volunteer Observing Ship (VOS) Programme. Through comparisons with carbon monoxide data of NIES VOS, the validity of the estimated fire-induced carbon emissions was demonstrated. The best estimate, which used both aircraft and shipboard CO_2 observations, indicated 273 Tg C for fire emissions from September–October 2015. This 2-month period accounts for 75 % of the annual total fire emissions and 45 % of the annual total net carbon flux within the region, indicating that fire emissions are a dominant driving force of interannual variations of carbon fluxes in Equatorial Asia. In future warmer climate conditions, Equatorial Asia may experience more severe droughts, which risks releasing a large amount of carbon into the atmosphere. Therefore, the continuation of aircraft and shipboard observations is fruitful for reliable monitoring of carbon fluxes in Equatorial Asia.

Key Words: inverse modeling, aircraft observations, ship observations, carbon dioxide

Estimating regional emissions of synthetic greenhouse gases and ozone depleting substances based on atmospheric observations

Sunyoung Park[1*], Hyeri Park[1], Haklim Choi[2]

1. Department of Oceanography, Kyungpook National University, Daegu, Republic of Korea
2. Kyungpook Institute of Oceanography, Kyungpook National University, Daegu, Republic of Korea

Abstract

Many man-made halogenated compounds such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfurhexafluoride(SF_6) are thousands of times more potent than CO_2 in terms of their Global Warming Potentials (GWPs). CFCs and HCFCs are also targeted for emission regulations by the Montreal Protocol on ozone depleting substances (ODSs). While emissions of these industrial gases from the large economies of East Asia must be one of the most significant environmental concerns these days, identifying and quantifying their emission sources remain poorly studied due mainly to rapid evolution in industrial structure, resulting complicated emission patterns, and uncertainties in the reported emissions. Thus, there has been a consensus that atmospheric monitoring of these gases can validate the reported emissions, improve the emission estimations and eventually help establish effective regulation strategies.

In this presentation, I introduce continuous, in-situ, high-precision atmospheric observations of a wide range of halogenated compounds obtained at a regional monitoring site in East Asia (Gosan station, Jeju Island, Korea; 33°N, 126°E) since 2008 as part of the Advanced Global Atmospheric Gases Experiment (AGAGE). Gosan is ideally located with seasonally varying, distinctive wind patterns, which basically allow for monitoring both of polluted air masses from continental, regional sources and of clean Pacific and Siberian air masses reflecting global background levels. A recent study based on the Gosan observations for the regional emissions of banned ozone depleting CFC-11 (Rigby, Park et al., Nature, 2019; Park et al., Nature, 2021) is also discussed to demonstrate how crucial long-term, precise regional atmospheric measurements are in order to timely detect unexpected emission increases of controlled compounds and to ensure that international protocols continue to be implemented effectively.

Key Words: Atmospheric Observations, Synthetic GHGs, Ozone Depleting Substances, Gosan Station, Regional Emissions, East Asia

Integrated GHG observations in Korea

Haeyoung Lee*, Sangwon Joo, Young-Suk Oh, Sunran Lee, Samuel Takele Kenea, Soojeong Lee, Chu-Yong Chung, Yeon-Hee Kim

National Institute of Meteorological Sciences, Jeju, Korea

Abstract

To achieve the carbon neutral in 2050, Korea Meteorological Administration/National Institute of Meteorological Science (KMA/NIMS) has launched the INverse modeling for Validating and Evaluating of the Reduction of Sectoral greenhouse gas Emission in KOREA (INVERSE-KOREA) which was endorsed by World Meteorological Organization/Integrated Global Greenhouse Gases Information System (WMO/IG^{3}IS) in last May, 2021.

To implement INVERSE-KOREA, atmospheric measurement data became more important. There are various platforms to monitor atmospheric greenhouse gases (GHG) such as in situ surface stations, a remote sensing measurement, a flight, a tall tower and a vessel operated by KMA/NIMS. The measurement data have been accumulated from 1999 while those data are very limited for users. Therefore, as part of INVERSE-KOREA, we will provide the integrated greenhouse observation data through one portal to the public from 2022.

We also have started to develop the isotope and halocarbon measurement to analyze proxies of major greenhouse gases in cooperation with Korea Research Institute of Standards and Science. The greenhouse gas measurement network was extended to the Seoul megacity as installing a measurement system at Lotte Tower, which is known for the landmark of Seoul with 555 m, as including 3 other stations operated by Seoul Research Institute of Public Health and Environment. We also cooperate with Harvard medical school to develop the low cost and high precision sensor to fill the gap in national and local scale.

Here, the plan will be introduced for integrated observation data system with more detailed information.

Key Words: WMO/IG3IS, INVERSE-KOREA, Integrated observation, greenhouse gases

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