The 2nd International Workshop on Atmosphere Watch in Asia

Greenhouse Gases Monitoring Activities

October 21st – 22nd, 2010
Jeju KAL Hotel in Jeju, Korea
간지

- Program -
Program for the 2nd International Workshop on Atmosphere Watch in Asia
- Greenhouse Gases Monitoring Activities -

October 21st – 22nd 2010
Jeju KAL Hotel in Jeju, Korea

▶ Oral Presentation (October 21st)

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- Oral Presentation -
WMO/GAW Observation System and Greenhouse Gases

Hans-Eckhart Scheel\textsuperscript{a,*}, Oksana Tarasova\textsuperscript{a}, Liisa Jalkanen\textsuperscript{b} and Leonard Barrie\textsuperscript{b}

\textsuperscript{a} Karlsruhe Institute of Technology, IMK-IFU, Germany
\textsuperscript{b} Atmospheric Environment Research Department, World Meteorological Organization, Switzerland

The WMO Global Atmosphere Watch (GAW) Programme is the only existing long-term global programme providing an internationally coordinated framework for observations and analysis of the chemical composition of the atmosphere. GAW is a partnership involving contributions from about 80 countries. It includes a coordinated global network of observing stations along with supporting facilities (Central Facilities) and expert groups (Scientific Advisory Groups. SAGs and Expert Teams, ETs). Currently GAW coordinates activities and data from 27 Global Stations and a substantial number of Regional and Contributing Stations. Station information is available through the GAW Station Information System GANSIS (http://gaw.esa.ch/gawsis/).

There are six key groups of variables which are addressed by the GAW Programme, namely: ozone, reactive gases, greenhouse gases, aerosols, UV radiation and precipitation chemistry.

GAW works towards integrated observations unifying measurements from different platforms (ground based in situ and remote, balloons, aircraft and satellite) supported by modelling activities. GAW provides data for ozone assessments, Greenhouse Gas Bulletins, Ozone Bulletins and precipitation chemistry assessments published on a regular basis and for early warnings of changes in the chemical composition and related physical characteristics of the atmosphere.

GAW coordinates the activity of the greenhouse gas observational network through a number of mechanisms and insures its quality through a set of central facilities. The latter includes a Central Calibration Laboratory maintaining primary standards for CO, CH and N\textsubscript{2}O and the WMO World Reference Scale for greenhouse gases, World and Regional Calibration Centers maintained by WMO partners and Quality Assurance/Science Activity Centers. A rolling-review process for the data quality objectives and measurement requirements is performed through biennial WMO/IAEA Expert Workshops. Measurements data after quality control are submitted, archived and disseminated by the World Data Center for Greenhouses Gases (WDCC). This set of data is used for global products and assessments preparation, in particular the preparation of the annual Greenhouse Gas Bulletin.

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Introduction and Recent Topics for Atmospheric Carbon Cycle Researches In Meteorological Research Institute (MRI), Japan

Hidekazu Matsueda

Meteorological Research Institute, Japan

The Meteorological Research Institute/Geochemical Research Department (MRI/GRD) in Japan has been studying global and regional carbon cycles by various observations of trace gases in the atmosphere and ocean for more than 20 years. For the atmospheric researches, we have developed the long-term observations by using several platforms such as JAL aircraft, MRI meteorological tower as well as WMO/GAW ground-based stations operated by the Japan Meteorological Agency (JMA). We are also concerned with the development of new sampling and measurement techniques such as automated observation system on board the aircraft, electrostatic Rn-222 measuring system as well as spectroscopic multi-species analyzer, in collaboration with other Japanese Institutes of NIES and AIST. The collected data from the both MRI and JMA are analyzed to understand the sources/sinks of trace gases and their transport processes, in conjunction with 3-D model simulations. The new scientific products from the MRI are effectively used to advance the operational monitoring programs of the JMA headquarter. In this presentation, we will introduce our MRI research activities as well as recent topics related to the JAL observation project (Comprehensive Observation Network for Trace gases by AirLiner: CONTRAIL).
Greenhouse Gases Monitoring Activities in Korea Global Atmosphere Watch Center (KGAWC) and Future Plans

Han-Chol Lim*, Sung-Jin Kim, Im-Chul Shin, Chang-Soo Park, Il-Yong Lee and Sang-Hoon Kim
Korea Global Atmosphere Watch Center, KMA, Republic of Korea

The KGAWC belongs to the regional station (registration number: 47132) since 1998, and the Center has been actively engaged in international activities, participating in intercomparison events, organizing international workshops, and sharing data from WDCGG (World Data Centre for Greenhouse Gases). Due to its relatively pollution-free environment, KGAWC provides an ideal site for observations that are geographically representative of the background atmosphere of Northeast Asia including the Korean Peninsula (Fig. 1). At present, 36 parameters, including greenhouse gases, aerosols, ultraviolet radiation, ozone, and precipitation chemistry, are being measured at the Center.

KGAWC endeavors to measure more various greenhouse gases and tries to construct global observation networks. The greenhouse gases observed in KGAWC are totally 7 species, such as Carbon Dioxide (CO₂), Methane (CH₄), Nitrous Oxide (N₂O), Chlorofluorocarbons (CFC11, CFC12, CFC113), and Sulfur Hexafluoride (SF₆), and they have been measured since 1999, but CFC113 and SF₆ are added in 2007. The developed QA/QC procedures based on the GAW report No. 184 are performed for all observations of greenhouse gases. KGAWC measures concentration of greenhouse gases by both aircraft and ship in 2010 for data acquisition of greenhouse gases around the Korean peninsula as well as are preparing to register the Antarctic King Sejong station to one of the GAW global stations.

KGAWC also have a lot of interests to data application and display of information for concentration of greenhouse gases observed for 11 years. So, we are to develop an assessment technique and practical information for concentration of greenhouse gases in background atmosphere. In this presentation, we introduce the outline of change of greenhouse gases concentration over the Korea peninsula in 2009 (Fig. 2), and discuss about the newly developing assessment technique of greenhouse gases concentration in background atmosphere.

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Fig. 2. Annual averages of GHGs (CO₂, CH₄, N₂O, CFCs) concentrations for 1999–2009.
Greenhouse Gases Measurement at Global Atmosphere Watch (GAW) Bukit Kototabang, West Sumatra – Indonesia

Alberth Christian Nahas*

Global Atmosphere Watch (GAW) Bukit Kototabang, The Indonesia Agency of Meteorology Climatology and Geophysics (BMKG), Indonesia

The measurement of greenhouse gases (GHGs) mixing ratio at Bukit Kototabang, West Sumatra – Indonesia, has been conducted since 2004. This measurement is a part of NOAA ESRL Global Monitoring Division on Carbon Cycle Greenhouse Gases (CCG). Passive method is used on this measurement. Ambient air from 32 m tower was drawn and to be filled into two glass cylinders of Airkit Flask Sampler. Sampled cylinders were then shipped to CMDL NOAA for further analysis. There are four main GHGs measured: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and sulfur hexafluoride (SF₆). Result showed that on the period ranging from 2004 to 2009, positive trends were showed for CO₂, N₂O, and SF₆. Meanwhile, CH₄ showed stability with slight tendency on the positive trend. Result also showed a seasonal pattern, particularly for CH₄, N₂O, and SF₆. This pattern was strongly influenced by air mass transport due to yearly revolution of the Earth around the Sun. Average year on year growth rates of CO₂, CH₄, N₂O and SF₆ mixing ratio in the period of 2004-2009 are 1.8 ppm/year, 2.5 ppb/year, 0.8 ppb/year, and 0.26 ppt/year, respectively.

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Development of International VOC Standards for GAW Measurement of Background Monitoring on Earth

Gwi Suk Heo*, Yong-Doo Kim, Mi-Eon Kim
Korea Research Institute of Standards and Science, Republic of Korea

Measurement of VOCs are very important to understand ambient air chemistry which is directly related to pollution control and the species should be monitored between nations. and also VOCs are the possible target chemicals which are effecting climate change as like other green house gases. Several monitoring sites around world are already monitoring these chemicals to look closely the relevance of the chemical species to earth environment. Since the annual amount change of VOCs is too small to trace, very accurate measurements are necessary to achieve the goal of understanding of phenomena on earth. Presently GAW sites use standards of VOC with large uncertainty which are too large to measure any annual trend of VOC. Therefore four NMI(National Metrology Institute) are working together to solve the problem. KRISS(Korea), NIST(USA), NPL(UK) and VSL(Netherland) four NMI are working with other GAW network labs for developing better standards for VOC measurement. KRISS is working for development of standards for DMS(dimethylsulfide) and MeCN(acetonitrile), and also developing HCHO(formaldehyde), and NMHC(nonmethane hydrocarbons). Preparation method for developing the DMS, MeCN, HCHO standard will be presented and discussed.

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Recent Findings from Observations of GHG Emissions at Gosan, Jeju Island, Korea

Kyung-Ryul Kim1, Jooil Kim1, Shanlan Li1, Mi-Kyung Park1, Seung-Kyu Kim1, Juns Muhle2, Ray F. Weiss2

1 Seoul National University, Rep. of Korea
2 Scripps Institute of Oceanography, UC San Diego, USA

Measurements of greenhouse gases (GHGs) at Gosan, located on the south western tip of Jeju Island, Korea, have been a source for great insight into the emissions of GHGs in the East Asia. Here, we highlight some of the recent findings and current research topics from our measurements at Gosan.

Recent analysis in Chinese emissions of halogenated species at Gosan (Kim et al., 2010) confirm that China is now a dominant emission source of various anthropogenic halogenated species, including CFCs, HCFCs, HFCs, PFCs, and SF6. Of note, we find large emissions of some HFC compounds which were known to be used mostly in developed countries and not in China. Continued monitoring and analysis of emissions from China should show future changes in emission patterns as China adapts to the MontrealKyoto and future environmental protocols. Advanced inversion modeling analysis of emissions using FLEXPART came to similar conclusions (Stohl et al., 2010), and incorporating new analysis methods should help provide a deeper understanding of emission patterns and changes in China as well as in all of East Asia.

A study of global historical SF6 emissions (Rigby et al., 2010) performed with global measurements of SF6 in both the Advanced Global Atmospheric Gases Experiment (AGAGE) and National Oceanic and Atmospheric Administration (NOAA) networks as well as Gosan showed that the current discrepancy in top-down and bottom-up emissions of SF6 are likely to be explained by emissions in East Asia, and calls for regional emission modeling efforts to further verify the SF6 emissions in this region.

Finally, top-down global emissions of perfluorinated carbons (PFCs) CF3, C2F6, and C3F8 were recently published (Muhle et al., 2010). While the study did not use Gosan measurement data directly, it identified a large imbalance between the reported PFC emissions from the aluminum and semiconductor industries compared to the global total emissions deduced from measurements. East Asia is most likely to play an important role in explaining this imbalance, and an in-depth study using Gosan data on this subject is currently in progress.

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References:
Stohl, A., et al. (2010). Hydrochlorofluorocarbon and hydrofluorocarbon emissions in East Asia determined by inverse modeling, Atmos Chem Phys, 10(8), 3545-3560. doi:10.5194/acp-10-3545-2010
Observation of Atmospheric Radon-222 with a New Measuring System at the WMO/GAW Monitoring Stations of JMA in Japan

Kazuhiro Tsuboi
Meteorological Research Institute, Japan

A new compact radon measuring system has been developed for high-resolution observation of low-level radon-222 (Rn) for the remote sites, in collaboration with the MRI and AIST. The Rn measuring system was installed at three WMO/GAW stations of Minamitorishima (MMN), Yonagunijima (YON), and Ryori (RYO) operated by Japan Meteorological Agency (JMA). The Rn measurements clearly show that distinct seasonal variations as well as frequent episodic events with Rn enhancement peaks on a synoptic scale are successfully captured at two island stations of MMN and YON during more than 3 years, while the observation at the RYO station stared in this year. The 3-D transport model simulation clearly reveals that the Rn enhancement events are driven by the Asian continental outflow due mainly to the passage of the cold front associated with the moving depression. Comparing with other trace gases observed simultaneously at the stations, significant correlations between the Rn and other trace gases were found for the most of the synoptic-scale events, indicating a large impact of widespread pollutions from the East-Asian countries on the regional air quality over the western North Pacific.

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Measurements of CO₂ Concentration at the Antarctic Peninsula

Taesin CHOI*, Namyi CHAE, Young Joon YOON and Bang Yong LEE
Korea Polar Research Institute, Republic of Korea

Additional measurement of atmospheric CO₂ concentration based on Cavity Ring-Down Spectroscopy (CRDS) is needed at the Korean Antarctic King Sejong Station (KSJ). Antarctic Peninsula mainly due to 1) the projected change in Southern Ocean uptake for the atmospheric CO₂ caused by climate change, 2) the possible increase in contamination sources by frequent and increased visits for research and tour, 3) increase in research instruments at the station in spite of limited man-power, 4) educational use, 5) preparation for green-house gases monitoring at another Korean Antarctic Station in advance, and 6) the enhanced network for CO₂ monitoring over the Pacific Ocean side of Antarctica based on two Antarctic Station and one Ice-breaking R/V (ARAON). CRDS CO₂ analyzer was set up in January, 2010 at KSJ with collaboration of KMA and KRISS and has been operated over nine months. Based on the preliminary results, its performance is stable based on the calibration by using standard gases at an interval of 15 days. At the presentation, we will report the CRDS analyzer performance with preliminary CO₂ concentration results in detail and operating strategy.

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Remote Observation Techniques for Monitoring Greenhouse Gases

Jin Seog Kim*, Dong Min Moon, Jin Bok Lee

Korea Research Institute of Standards and Science, Republic of Korea

To accurately judge and respond to factors affecting climate change, one should watch materials causing climate change from various locations at the WMO level in an efficient manner. As a powerful means to conduct such watching activities, we have developed related technologies for remote monitoring system such as automated sample pretreatment, remote calibration, remote analytical equipment operation and remote data management. These techniques have been applied to Ulleung island observation site in East Sea of Korean peninsula to monitor CO₂ and CH₄ since April, 2010. CRDS CO₂/CH₄ instrument are adopted with two calibration gases, mass flow controller and cryogenic water removal system. During last 6 months we have improved water vapor removing system and valve controlling system.

We also developed remote sampling system to take air sample from Beakryeong island weekly. This system is operated in KRISS at our desiring time to take air sample up to 6 bar in 1 L canister through internet communication. Sampled air will be analyzed CO₂, CH₄, NO, SF₆, and CO in KRISS.

Remote observation techniques for monitoring greenhouse gases will contribute to activity of global atmospheric watch program.

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Optical Remote Sensing of Atmospheric Trace Gases and Aerosol

Young J. Kim* and Jihyo Chong

Gwangju Institute of Science and Technology, Republic of Korea

Optical remote sensing techniques have been preferred for measurements of atmospheric trace gases and aerosol because they allow direct measurement without pre- and/or post-calibration in the laboratory. Since the 1970s, Differential Optical Absorption Spectroscopy (DOAS) has been used as a powerful tool for ground-based optical remote sensing of atmospheric trace species (e.g., SO₂, NOₓ, O₃, HCHO, BrO, ClO, and VOCs) and aerosol. In addition, atmospheric trace gases are measured by satellite remote sensing (e.g., MODIS, OMI, GOME, SCIAMACHY, and GEMS) using their unique absorption features in the UV and visible regions. Ground-based Multi-Axis DOAS (MAX-DOAS) measurements were carried out to investigate SO₂, NOₓ, and ClO levels in the mid-latitude boundary layer. This ground-based instrument measures the scattered sunlight from different viewing directions with several telescopes to measure slant column density (SCD) of atmospheric trace gases. While MAX-DOAS measurement enables the retrieval of the distribution of trace gases, the more recently developed Imaging DOAS technique provides information on the spatially resolved two-dimensional distributions of trace gases. I-DOAS measurements were conducted to investigate NOₓ levels in fossil fuel power plant plumes and over an urban area. Additionally, MAX-DOAS has been utilized in recent years as a means of deriving vertical profiles of aerosol. DOAS technique has been applied as an alternative tool for the detection of atmospheric aerosols. Based on an aerosol retrieval algorithm and a model study, the aerosol information (e.g., aerosol optical depth (AOD) and vertical distributions of aerosol extinction coefficients (AECs)) of the lower troposphere can be retrieved. The satellite remote sensing approach associated with the spectral DOAS fit technique has been successfully employed for the measurements of tropospheric trace gases on global and regional scales. The retrievals of tropospheric traces gases (NC and SO₂) from SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) onboard the ENVISAT satellite is presented. Satellite measurement of trace gases in the atmosphere is a crucial step forward for real-time monitoring and forecasting of air quality on regional scale. Optical remote sensing can provide climatology of trace gases and aerosol with higher spatial resolution.

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Global CO₂ and Temperature Monitoring with PGGM and FORMOSAT-3/COSMIC

Kuo-Ying Wang*, Shih-Wan Chang, Teng-Chun Chang, Chi-Cha Wang, Ching-Jui Chiu, Jian-Cyuan Wang, Ka Wa Chan, Pei-Lun Hsieh, Pei-Yu Huang

Department of Atmospheric Sciences, National Central University, Chung-Li, Taiwan

Atmospheric carbon dioxide concentrations and global temperatures are two keys for observing present climate and for predicting future climate change. Human emit about 30 billion tone of carbon dioxide each year. About half of these emissions remain in the atmosphere, while the rest are absorbed by terrestrial vegetation and oceans. What are the temporal variations and spatial distributions of carbon dioxide absorbed by the vegetation and oceans? Can these natural absorbers continuously provide human such a great buffer for the carbon dioxide that human has been enjoying for the past 50 years? In a world with projecting increase in fossil fuel usage, changes in the capability of these natural processes in absorbing carbon dioxide from the atmosphere remains unknown. Ground-based stations such as Mauna Loa and other NOAA CMDL stations continuously provide excellent long-term measurements of carbon dioxide. These stations are good in showing long-term trend of carbon dioxide in the atmosphere. However, station-based data are limited by its spatial coverage. They cannot answer where and when the carbon dioxide has been absorbed over the oceans and terrestrial vegetation. Until we are able to proactively go out to measure carbon dioxide in the air above oceans, in the surface ocean, and over the forests, our understanding of where and when the carbon dioxide has been absorbed each year remains elusive. Hence, measuring carbon dioxide on a global scale has become a top priority for the past few years by top international institutes. These efforts include the Japanese GOSAT (Greenhouse gas observing satellite), successfully launched on 23 Jan 2009; the US OCO (Orbiting Carbon Observatory), launched on 24 Feb 2009 but was unable to reach the orbit; the US HIPPO project; the Japanese CONTRAIL project; the EU MOZAIC and IAGOS-ERI projects; the EU ICOS project; and the EU CARVASSO and CARBOOCEAN projects.

On the other hand, observations of global temperatures contain uncertainties. Conventional observations (synoptic observations) are mainly provided by ground-based stations and radiosonde stations. Asynoptic observations are provided by ships, buoys, pilots and profilers, aircrafts, and satellite radiance retrieval. Since temperature observations are widely used as a key parameter to characterize current climate and climate trends, the use of more accurate temperature measurements can significantly improving our understanding of current climate and climate trends.

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The main purpose of this project is to produce accurate, long-term, and sustainable measurements of carbon dioxide over the oceans and terrestrial vegetations from commercial in-service cargo ships and aircrafts; and to produce better estimates of global temperature trends using temperature measurements from FORMOSAT-3/COSMIC GPS radio occultation measurements. In doing so, we can help track global distributions of carbon dioxides following their emissions on a finer temporal and spatial scales, and try to work out a genuine global temperature distribution in the context of rising carbon dioxide concentrations. A better knowledge of global carbon dioxide distribution can lead to better estimates of the sources and sinks of carbon dioxide from regional to global scales; a better knowledge of global temperature distribution can contribute to the assessment of current and future climate trends. These efforts are expected to play a significant role as the world moving toward a more stringent control of global carbon emissions and as the world entering a new decade predicted to be warmer than the 2000-2009. In addition, this project will expand the current global carbon dioxide observations now undertaken by international projects such as GOSAT, CONTRAIL, HIPPO, AQUA AIRS, ICOS, IAGOS-ERI, CARWASSO, and CARBOOCEAN; and the current global temperature observations undertaken by earth-observing satellites.
KoFlux Carbon Flux Monitoring: Inter-Disciplinary Collaboration and Learning

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Quantifying and understanding carbon cycle over complex ecosystems depends on inter-disciplinary collaboration among scientists. Monitoring of carbon cycle through the synergy of measurement, modeling, and satellite image is thus imperative to advancing the understanding of carbon cycle and its change as well as predicting weather and climate. Based on KoFlux infrastructure, collaborative research focuses on linking in situ measurement, ecological modeling, and remote sensing to bridge the gaps between different scales of carbon exchange processes in heterogeneous and complex Korean landscapes. Carbon flux data over multi-year eddy covariance measurements have been obtained and used for validating various modeling and remote sensing products. In this presentation, we summarize the research highlights and introduce how the findings are contributing to the development of regional and international projects such as CarboEastAsia. Furthermore, we introduce how this eddy covariance measurement can be applied with cavity ring-down spectroscopy (CRDS) technique to measure greenhouse gas such as CH4 and CO2 fluxes.

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Development of a Global Atmospheric Transport Model and Its Application for Carbon Cycle Studies

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Atmospheric transport model is a powerful tool for understanding C\textsubscript{2}O dynamics in the atmosphere and exchanges of C\textsubscript{2}O with the land biosphere and the oceans. In the Meteorological Research Institute, we are developing a global three-dimensional transport model based on a general circulation model in cooperation with the University of Tokyo and Japan Agency for Marine-earth Sciences and Technology (JAMSTEC). The model used here has advantages for conserving tracer mass and also for multi-scale simulation and Eulerian back-trajectory simulation on the common framework. Simulated results are evaluated with the measurements from the global surface observation networks as well as our JAL aircraft observations. Furthermore, by the inverse method, we optimize regional carbon budget and then obtain realistic three-dimensional mapping of atmospheric C\textsubscript{2}O for the global and regional carbon cycle studies. The coordinated sensitivity experiments using the model also help us to better understand source/sink mechanism and transport process of C\textsubscript{2}O. In this presentation, a brief description of our transport model and some simulation results will be introduced.

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Carbon Tracker-Asia

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CarbonTracker (CT) is a new product that combines measured atmospheric concentrations with other information to enhance the utility and value of carbon cycle information to society, economies and ecosystem management, as we respond to the climate related challenges of the 21st century. The additional information consists of independent estimates of emissions and removals of CO2 by terrestrial ecosystems and the oceans, as well as emissions from fossil fuel burning and wildfires. CT was originally developed by NOAA’s Earth System Research Laboratory to focus on North America. Here the system is applied in Asia as CarbonTracker-Asia.

Using inverse techniques, global distributions of CO2 concentration and fluxes (terrestrial ecosystem and ocean) are obtained from CT that is optimally consistent with both atmospheric transport and observations. An optimization procedure is performed by a fixed-lag ensemble Kalman smoother implemented within the TM5 atmospheric transport model.

And CT-Asia uses a nested grid to provide enhanced transport resolution over Asia and has been adapted to account for surface conditions in Korea. All our results are available through:

http://www.nimr.go.kr/metri_home/english/Laborato

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The CSIRO Collaborative GHG Observation Network for Southeast Asian – Australian Region.

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A high precision atmospheric observation network for greenhouse and related trace gas species is being expanded in the Southeast Asia-Australian region. The primary objectives of the network are to:

1. Improve our global understanding of the forcing of climate change by providing observations of climatically active atmospheric constituents in the critically under-sampled tropical latitudes, and
2. Dramatically reduce the uncertainties in estimates of GHG emissions from Australia.

The Australian regional network has the Cape Grim Baseline Air Pollution Station (GAW) as the central observation site. A new atmospheric observation site has recently been established at Gunn Pt. (near Darwin in the Northern Territory) in the Australian tropics region. This site incorporates high precision in-situ measurement and flask air sample collection programs for a range of greenhouse and related trace gas species. It is anticipated high precision atmospheric observations from this region should significantly improve the understanding of the tropical sources and sinks of the major anthropogenic greenhouse gases (CO₂, CH₄, N₂O). High precision "LoFlo" (NDIR) and "Picarro" (Cavity Ring Down Spectroscopy) instruments are being used for the measurement of CO₂, CH₄ and CO₂/CO₂. The research program and preliminary data from this new site and collaborative programs at sites in the Asian tropical region at Cape Rama, India (NIO) and Danum Valley GAW station, Malaysia (MMD) will be discussed.

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Current Status and Future Prospects of Greenhouse Gas Observations in East Asia as seen from WDCGG Data

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The Japan Meteorological Agency (JMA) has operated the WMO World Data Centre for Greenhouse Gases (WDCGG) since 1990. Data for greenhouse gases have been reported to the WDCGG from different data contributors in East Asia, obtained at fixed stations and on board ships and aircraft. The data may be based on different calibration scales from the latest WMO scales. Comparison of measurements by circulating reference gases is organized regularly in the framework of GAW. JMA organizes such comparison for methane in Asia and the South-West Pacific as a GAW World Calibration Centre.

Regional issues to be addressed by the GAW participants in East Asia may be identified by analyzing the current status of data archives at the WDCGG and participation in comparison activities in the region. Such issues include gaps in observations and data and different calibration scales. More intensified comparison of greenhouse gas measurements and exchange of observational data might be suggested among the regional participants, so that GAW can properly meet the needs from the region as well as the global needs for regional activity.

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The Role of CCLs and WCCs In the GAW Programme for the Observation of Greenhouse Gases

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The activities within the World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) programme are guided by Strategic Implementation Plans (GAW Reports No. 142, 156, 172). These plans define the mission, set out the main long-term objectives, and describe implementation principles. Since the inception of GAW in 1992, the attention paid to issues of quality assurance and quality control (QA/QC) has grown and has resulted in major advances. Network-wide compatibility of greenhouse gas observations (CO₂, CH₄, N₂O and SF₆) from different laboratories is a major goal of the respective Central Calibration Laboratories (CCL) and World Calibration Centres (WCC). A CCL maintains the primary standard for a particular variable, and thus one single scale for use in the world-wide network. It also supplies calibrated air standards to GAW analytical laboratories and for intercomparisons. CCLs should ensure that calibration scales are and remain traceable to SI units and be working closely with metrology institutes and the BIPM. WCCs, in spite of their name, are not supposed to perform their own calibrations, but their laboratory standards are directly linked to the respective CCL. Major tasks of a WCC are the development of quality control procedures, conducting audits at stations and intercomparison exercises as well as providing technical advice to GAW station personnel. The CCLs for CO₂, CH₄, N₂O and SF₆ are operated by NOAA/ESRL (USA). JMA (Japan) is in charge of a CH₄ WCC for Asia, WCC-Espa (Switzerland) hosts the WCCs for CH₄ (Am, E/A) and for CO₂, while the WCC-N₂O is operated by KIT IMK-IFU (Germany).

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Traceability for Monitoring Greenhouse Gases and WCC

Invitation

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Greenhouse gases (GHG) have been known as causing materials of the greenhouse effect. Because it is very important to reduce their emission, they have been paid attention since Kyoto protocol to the United Nations Framework Convention on Climate Change. Accurate observation data of ambient GHG are vital for the study of the relationship between GHGs and global warming, but it is not easy to quantify their mixing ratios owing to their globally and temporally tiny variation. For example, mixing ratio of carbon dioxide in the atmosphere is reported to be growing by +1.7 ppm (parts per million)/year for recent 10 years according to GAW report.

For the purpose of accurate measurement of GHGs, WMO-GAW have paid attention to systematically improve quality of data observed at the global or regional monitoring site. To produce good measurement data, it is essential to ensure traceability over the world as well as to establish a controlled quality system. Based on WMO Global Atmosphere Watch (GAW) Strategic Plan: 2006-2015 (GAW report 172) the central calibration laboratory was almost established. At the present KMA is preparing to invite the WCC by means of a cooperation with KRISS.

From 2002 KRISS started development of the standard gas mixtures of CO2, CH4, N2O, CFCs. For CO2, CH4, and N2O KRISS showed appropriate results through key comparisons (such as C3CM-K52, 68 and P41) performed by BIPM. KRISS has participated in Round Robin test (RRT) carried out by CH WCC (Japan Meteorological Agency). We have prepared and maintained the standard gas mixtures of ambient level SF6 by using a gravimetric method. KMA has observed it since 2007. The traceability of the SF6 is from 'Certification and measurement capability' published by BIPM until now. A round robin test will be proposed after any transfer standards which are traceable to CCL are prepared. Therefore this presentation aims at an introduction of background and report a progress for SF6 WCC preparation.
The 2nd International Workshop on Atmosphere Watch in Asia
–Greenhouse Gases Monitoring Activities–

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- Poster Presentation -
Greenhouse Gases Monitoring Activities of Korea Meteorological Administration

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Korea Meteorological Administration (KMA) has contributed the WMO Global Atmosphere Watch (GAW) program since December 1996. There are two regional GAW stations on the operational basis. One is Anmyeon-do (#47132) which is an integrated observation site: the other is Pohang (#332) which is a stratospheric ozone observation station. A variety of atmospheric species are monitored at the Anmyeon-do station such as greenhouse gases (GHG), reactive gases, aerosols, atmospheric radiation, stratospheric ozone and UV-radiation and precipitation chemistry. In the Anmyeon-do station, 5 species of greenhouse gases (CO2, CH4, N2O, CFC-11 and CFC-12) have been measured since 1998 and recently chlorofluorocarbon-113 (CFC-113) and sulfur hexafluoride (SF6) have been monitored since 2007. In addition, the measurement of PFC-14 (CF3) has been started in 2010. For the past 11 years, the growth rate of CO2 of the Anmyeon-do station was 2.2 ppm yr^-1. The annual mean CO2 concentration of 2009 reached 392.5 ppm that is 6.2 ppm higher than the global average of 386.3 ppm for the same year as documented by NOAA/GMD. All GHS measurements were calibrated using the standard gases provided by the Korea Research Institute Standard and Sciences.

Since East Asia is one of the rapidly developing regions in the world, the representativeness as a background atmosphere monitoring site is very important. In the circumstances, KMA made a plan to expand the GHS observation network and a new station was established at Gosan in Jeju-do in the late 2008. Gosan is well known as an international super site as a background region which is located at the southern part of Korea. The domestic in-situ GHS measurement network of KMA will be complete by 2011 as establishing the Ulleung-do station which is located at the eastern part of Korea. It is, therefore, expected that the triangle-shaped GHC network after 2011 plays an instrumental role to measure GHC which are originated from the East Asia and are transported to the Pacific.

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New Possibilities for Remote Analysis of Atmospheric Aerosol Profiles by DOAS and LIDAR

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Information on the vertical distribution of aerosols is important for understanding their transport characteristics as well as radiative effect. In order to establish effective control strategies for aerosols in areas of interest, it is important to understand their chemical and physical properties including spatial and temporal distributions in the atmosphere. The multi-wavelength (3β + 2α + 1δ) Raman lidar system can measure vertical profile of optical properties of atmospheric aerosols such as extinction coefficients at 355 and 532 nm, particle backscatter coefficients at 355, 532, and 1064 nm, and depolarization ratio at 532 nm. In addition to the vertical distribution, microphysical properties of aerosol can be also retrieved by an inversion algorithm. The incomplete overlap between the telescope field-of-view and distance between telescope and transmitting laser significantly affects lidar measurement in the near field range, resulting in high uncertainty near the surface. Differential Optical Absorption Spectroscopy (DOAS) technique has been applied as a complementary tool for the detection of atmospheric aerosols. The Multi-Axis DOAS (MAX-DOAS) technique is a passive DOAS technique that uses scattered sunlight as a light source from several viewing directions. Measurements under low-viewing angles are associated with the absorption path in the lowermost atmospheric layer and the sensitivity for absorbers in the boundary layer is strongly enhanced. Recently developed aerosol retrieval algorithm based on O4 slant column densities (SCDs) measured at UV and visible wavelengths has been utilized to derive aerosol information (e.g., aerosol optical depth (AOD) and vertical distributions of aerosol extinction coefficients (AECs)) in the lower troposphere. Ground-based measurements of tropospheric aerosol using a MAX-DOAS system and a multi-wavelength Raman lidar system were conducted 28 ~ 30 May and 4 ~ 8 June 2005 at the Korea Global Atmosphere Watch Observatory (KGAWO) (36.56°N, 126.47°E), located in Aumyeon Island off the west coast of Korea. The aerosol extinction coefficient at 355 nm was retrieved for the 0–1 and 1–2 km layers using the MAX-DOAS data retrieval. Correlations coefficients (R²) of 0.70 and 0.35 were obtained for the 0–1 and 1–2 km layers, respectively between the aerosol extinction coefficients (AECs) obtained by MAX-DOAS and those by lidar measurements. Integrated measurements using a multi-wavelength Raman lidar and MAX-DOAS allow complete monitoring of atmospheric aerosol vertical profiles for better estimation of their radiative effects on atmosphere environment and climate change.

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Monitoring of CO$_2$ and CH$_4$ in Korean Peninsula

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Korea Meteorological Administration (KMA) tries to increase the number of atmosphere watch site in Korean Peninsula in order to monitor the emission of greenhouse gases more efficiently and accurately. It is important to choose the representative network site which can cover most of emissions on the peninsula and to manage observation laboratories more economically.

In this study, we developed an automatic remote system to monitor amounts of CO$_2$ and CH$_4$ in background air, and established the system in the Ulleung island. The Ulleung island was specially chosen, because it is located in the East Sea whereas other observation sites have been established at Anmyeon and Jeju island by KMA. The CRDS (Cavity Ring-Down Spectroscopy, Piccaro Inc., USA) was utilized to measure the CO$_2$ and CH$_4$ concentration in the ambient air after passing through a humidifier. The humidifier composed with two kind refrigerators can reach until 2 ℃ and -65 ℃ respectively, and maintained the moisture contents in air sample less than 0.01 mmol/mol. In order to obtain accurate measurement data, we calibrate the CRDS every 2 weeks by one reference gas mixture, which contains 404.41 μmol/mol CO$_2$ and 1.934 μmol/mol CH$_4$ in air. If the difference between measured and reference values shows larger than 0.1 μmol/mol for CO$_2$ and 0.002 μmol/mol for CH$_4$ respectively, we calculate new slope of the calibration curve and replace it in the CRDS. The trend of observation data for Ulleung island will be presented together with data from other two sites.

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Development of Sulfur Hexafluoride (SF₆) Certified Reference Materials at Ambient Level

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Global mean concentration of SF₆ in 2009 was 6.5 pmol/mol which is much lower than other major greenhouse gases. Nevertheless, the global warming potential of SF₆ is much higher than other greenhouse gases due to its long lifetime in atmosphere, which is approximately 3200 years (IPCC, 2007). At present, semiconductors and display TV industries are expended dramatically in Korea, and these IT industries use SF₆ in etching and cleaning process. From 2007, Korea Global Atmosphere Watch Center (KGAWC) has monitored SF₆ at Anmyeon island. SF₆ concentration in Anmyeon island showed a little higher than global mean value, which is about 7.5 pmol/mol in 2009 (KMA, 2010).

In this study, we developed SF₆ certified reference materials at ambient level. In order to prepare gas mixtures with low concentration SF₆, pure SF₆ gas (99.9 %, Matheson Triga, USA) was diluted 6 times by pure nitrogen gas (99.9999 %, Deokyang Energen Co., Korea) in the 6.4 L aluminum cylinder which has polish treated on the inner surface (Luxfer, Australia). And the substitutional gravimetric method was adopted to prepare mixtures. Impurity analysis in pure nitrogen is one of the important factors to prepare accurate reference materials. Thus, the amount of SF₆ in dilution gas largely affects to the preparation of SF₆ standard gas mixture particularly in low concentration. Therefore we measured SF₆ in pure nitrogen using a cryogenic pre-concentration system attached to the GC/ECD and confirmed that only less than 0.01 pmol/mol of SF₆ existed in pure nitrogen gases.

As a result of this study, we developed a set of ambient level SF₆ reference gas mixtures with standard uncertainty of 0.5 %, which taken from verification and gravimetric preparation uncertainties. KRISS and KGAWC used these SF₆ standard gas mixtures as references for analysis of sample cylinders, which were provided by WMO as Round Robin Test (RRT).

< References >

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Comparison for Vertical Distribution of Greenhouse Gases Between Aircraft-based and Satellite-based Measurements at GAW site In Anmyeondo

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1. Introduction
Vertical profile of greenhouse gases was measured using aircraft-based canister sampling at GAW (Global Atmosphere Watch) site, Anmyeondo (36°32'N, 126°19'E), on 27 May 2007 as a branch field observation of 2010 ARES (Atmospheric Radiation and Environmental Species) experiment. After air sampling, five species (CO, CH₄, NO, SF₆, CO₂) were measured using various gas analyzers with national standard gases to make sure of traceability. For validation of Anmyeondo profiles, 10-year-averaged monthly-mean CO₂ profiles measured from air flask sampling at Zyryanka of West Siberia were compared (Arshinov et al. 2009). Monthly CO₂ profiles at Incheon and Narita from CONTRAIL (Comprehensive Observation Network for Trace gases by AirLiner) were also taken into consideration (Machida et al. 2008). For comparison, satellite-based CO₂ total column concentration and CH₄ sounding from AIRS/AQUA and IASI/METOP were compared with those from aircraft-based measurement at Anmyeondo.

2. Site and measurements
Anmyeondo, where air sampling was carried out, is well known as one of major GAW sites in Korea as well as is a geographically important station because of down-stream region of long-range transport from China.

Using stainless-steel canister and diaphragm pump, ambient air was sampled with 7-level heights from surface to 5 km (surface, 150, 300, 500, 1000, 3000, 5000 m) every five flights (2200, 0100, 0400, 0600 and 0900 UTC). Most moisture in sampled air was trapped through chemical moisture trap (MgCl₂) in order to minimize sample loss and to exclude measurement errors due to moisture. From dry air samples, four greenhouse gases (CO₂, CH₄, NO and SF₆) and one trace gas (CO) were measured by KRISS (Korea Research Institute of Standard and Sciences).

3. Results
It is found that CO₂ concentration in lower layers was less than upper layers. Diurnal cycle of CO₂ is also well described at surface. For example high CO₂ concentration at 0700 KST was rapidly decreased at 1000 KST. It is shown that Anmyeondo CO₂ profiles have similar vertical patterns of Incheon on July 2007 and Narita on May 2007. Comparison between Anmyeondo and Zyryanka gives slightly

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different results because of CO₂ uptake of fine forest in atmospheric boundary. In 10-year western Siberian air sampling, same patterns of CO₂ profile were only found from September to April. In order to compare air sampling CO₂ profiles with satellite-based CO₂ retrievals using AIRS/AQUA and IASI/METOP, the closest satellite observation point to Amneondo as well as satellite retrievals corresponding to air measurement time was selected. Considering that satellite-based CO₂ retrievals are weighted in mid-upper atmosphere, underestimated CO₂ concentration compared with aircraft based CO₂ measurement is reasonable. It is interesting that AIRS has relatively larger difference than IASI compared with air measurement. It is, however, needed that more experiment and comparison be carried out to result in general conclusion.

4. Conclusion

Comparison for vertical profiles of greenhouse gases between aircraft-based and satellite-based measurements at GAW site in Amneondo was carried out. Approximately, the pattern of CO₂ profile has a good agreement with other air sampling experiment. For satellite comparison, underestimated CO₂ retrievals were shown compared with air measurement. Further experiment and study is necessary.
Top-down Validation of Global and East Asian Emissions of Tetrafluoromethane (CF₄) and Hexafluoropropene (C₂F₆)

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CF₄ (tetrafluoromethane, PFC-14) and C₂F₆ (hexafluoropropene, PFC-116) are powerful greenhouse gases (100-year Global Warming Potentials of 7,390 and 12,200, respectively), and are mostly emitted during aluminum manufacture and semiconductor production. Global emissions of these species were recently reported by Mühle et al. (2010) using in situ measurements of the Advanced Global Atmospheric Gases Experiment (AGAGE) combined with a global 12-box inversion model. The study found a discrepancy of up to ~6 Gg/yr for CF₄ in recent years between their measurement derived (top-down) and industry-reported (bottom-up) emissions, and speculated that underestimated emissions from aluminum manufacture in China could be one of the sources of this discrepancy. In this study, we use in situ measurements taken at Cape Grim (Tasmania, Australia) and Gosan (Jeju Island, Korea) within AGAGE to estimate CF₄/CF₆ emission ratios (ER) from aluminum manufacture (in Australia) and semiconductor production (in Korea), deriving ERs of 0.11 (by mass) and 0.42 (by mass), respectively. Assuming that all emissions of CF₄ and CF₆ occur from just these two sources, industry-specific emissions of these compounds can be calculated from the following simple formulas:

\[ E_{\text{CF}_{4}/\text{CF}_{6}} = E_{\text{CF}_{4},\text{ind}} + E_{\text{CF}_{4},\text{sem}} \]  \hspace{1cm} (1)

\[ E_{\text{CF}_{6}/\text{CF}_{4}} = (E_{\text{CF}_{4},\text{ind}})^{0.11} + (E_{\text{CF}_{4},\text{sem}})^{0.42} \]  \hspace{1cm} (2)

whereby \( E_{\text{CF}_{4}/\text{CF}_{6}} \) and \( E_{\text{CF}_{6}/\text{CF}_{4}} \) are global emissions of CF₄ and CF₆ reported in Mühle et al. (2010), and \( R_{\text{ind}} \) and \( R_{\text{sem}} \) are the emission ratios of CF₄/CF₆ derived for the aluminum industry and the semiconductor industry, respectively, thus solving for the global CF₄ emissions from the aluminum industry \( (E_{\text{CF}_{4},\text{ind}}) \) and semiconductor industry \( (E_{\text{CF}_{4},\text{sem}}) \), respectively. Analysis of global CF₄ emissions from 1990-2008 show that bottom-up emissions reported by the International Aluminum Institute (IAI, 2010) are in good agreement with top-down emissions derived for the aluminum industry until 2005, after which time the industry reports are underestimated by ~2.8 Gg. On the other hand, semiconductor emissions derived in this study suggest that emissions in

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this sector may be larger than currently assumed. Furthermore, CF₃ emissions from China's aluminum industry in 2008 are calculated using both the method described above (substituting the global emissions for Chinese emissions) and an interspecies correlation method, using Chinese emissions reported by Kim et al. (2010) and Saito et al. (2010). Preliminary results show that China's emissions are larger than those estimated from industry reports (IAI, 2010: 1.29 Gg), and suggest that China may be a dominant source of discrepancy in the global budgets of CF₃ emitted from aluminum production. A direct inversion of atmospheric measurements at Gosan to solve for Chinese emissions of CF₃ is currently in progress, and should help reduce the uncertainties in our findings.

References
Emission Characteristics of HFC-23(CHF₃)/HCFC-22(CHClF₂) between Different Air Masses in Northeastern Asia

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HFC-23 (chlorodifluoromethane, CHF₃) is one of the major components in various refrigeration, is emitted mostly from developing countries, as its consumption is not limited until 2013 by the Montreal Protocol. In addition, HFC-23 (trifluoromethane, CHF₃), a by-product in the manufacture of HCFC-22, is also a powerful greenhouse gas. Here, we discuss the regional emission characteristics of these compounds based on high-frequency in-situ measurements using the “Medusa” GC-MS system. HCFC-22 and HFC-23 baseline concentrations measured at Gosan (Jeju Island, Korea) from November 2007 to December 2008 increased by 1.8 ppt/yr and 0.6 ppt/yr, respectively. Pollution events of these compounds were observed very frequently (e.g., ~2-3 times) at Gosan than baseline levels. All the measurement data were divided into four groups by simultaneously considering the ratio (HFC-23/HCFC-22) and concentration (HCFC-22) at Trinidad Head (TH, California, USA). The residence time of trajectories were then analyzed in each of the four groups. The results exhibited the existence of a strong correlation with air mass origin for each group: 1) Air masses originating from Siberia in the north and from the Pacific in the south had ratios of 0.06-0.12 and concentrations of 196.9-254.3 ppt which is highly comparable to background air at TH. 2) Air masses passing over the Southern China exhibited similar ratios but higher HCFC-22 concentrations. 3) Air masses passing over the Northern China had ratios of 0.12-0.21. 4) Air masses passing over Korea and/or Japan had ratios of 0.01-0.06. Our results suggest that the HFC-23/HCFC-22 ratio can be used as a good indicator for the assessment of the pollution with Chinese origin. We also confirmed differences in air masses traveling over Northern and Southern China, most likely due to differences in air mass travelling speed over these regions before arriving at Gosan. This signature may be treated as one of the critical components in identifying the emission sources from different parts of China.

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Net Ecosystem CO\textsubscript{2} Exchange In a Coniferous Forest In Korea

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Net ecosystem exchange (NEE) of CO\textsubscript{2} was measured in a coniferous forest using the eddy covariance method in order to (1) quantify the carbon balance, (2) characterize the seasonal variability in NEE, gross primary productivity (GPP), and ecosystem respiration (RE) and (3) examine environmental factors that control the variability in NEE, GPP and RE. We present the analysis of the data measured in 2008 and 2009 in Gwangneung Coniferous Forest (GCK) Korea. The vegetation type is dominated by Abies sp. with an average stand age of about 95 years. The average canopy height is about 23 m and plant area index varies 3.7 in the winter and 8 in the summer. The seasonality of GPP, NEE, and RE showed clear variation that followed the changes in seasonal leaf phenology and climatic conditions. On the seasonal basis, the spring was the most productive with the largest magnitude of NEE. During the summer monsoon (e.g., Changma), forest turned into a carbon source in the middle of the growing season, which resulted in decreased solar radiation (R\textsubscript{s}). The substantial decrease in R\textsubscript{s} reduced GPP but had almost no influence on RE. After Changma, the forest became a weak carbon sink and then a carbon source during the winter. The differences in NEE and GPP between the two years were associated with the differences in environmental conditions mainly in the winter and summer. RE showed no significant differences between the two years. The warmer winter in 2009 induced the onset of carbon uptake that was about a month earlier than that in 2008. Less frequent precipitation and lower cloud cover during the summer of 2009 resulted in higher \( R\textsubscript{s} \) and consequently more carbon uptake compared to 2008. Analyses of NEE for the complete two years (2008 and 2009) showed that the coniferous forest was a moderate CO\textsubscript{2} sink. Our results suggest that different environmental factors constrained the magnitude of NEE and GPP at different time.
Evaluation of Ecosystem Greenhouse Gas Emission by Integrated Technique of Eddy Covariance and Cavity Ring-Down Laser Spectroscopy (CRDS)

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The Asian region is going to play an important role on greenhouse gases (GHG) emission and the climate system due to ecosystem diversity, rapid land-use and cover change, and changing hydrological cycle associated with monsoon climate. In various ecosystems, numerous studies using closed-path eddy covariance technique have been conducted to quantify GHGs fluxes. In order to monitor these fluxes (e.g., CH₄ and CO₂), we combine two techniques: (1) cavity ring-down spectroscopy (CRDS) used by Korea Research Institute of Standards and Sciences (KRISS) and (2) eddy covariance technique used by KoFlux and AsiaFlux community. In this presentation, we introduce the current progress along with difficulties and challenges in employing these two techniques in various ecosystems in Monsoon Asia.