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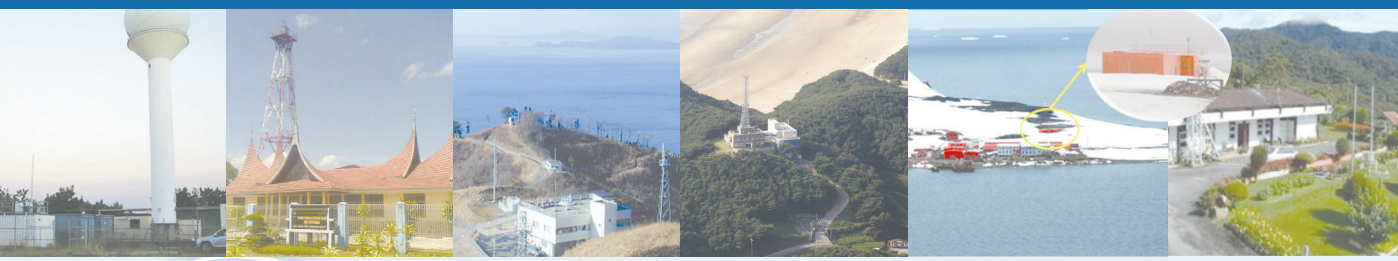

CSIRO BMKG JMA KMA KOPRI MET

Asian GAW Greenhouse Gases
Newsletter

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Countries are listed in alphabetical order.

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Contents of this article are contributed by participants in the 2nd workshop, and the next newsletter will be published in December 2012.

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Asian GAW Greenhouse Gases Newsletter

AUSTRALIA

CAWCR/CSIRO Collaborative GHG Observation Programs: Southeast Asia-Australia Tropics

M. V. van der Schoot (*Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research)*

Australia's Centre for Australian Weather and Climate Research (CAWCR) at CSIRO Marine and Atmospheric Research operate the GASLAB collaborative global greenhouse gas (GHG) observation network, which is based on in-situ measurements and/or collection of flask air samples (Refer Figure 1). Although the data collected from this network is regularly used in global carbon cycle studies, the main focus of this network is for carbon cycle research applications in the Southern Hemisphere. A primary application is the study of the efficiency of the Southern Ocean to sequester anthropogenic carbon dioxide (CO_2) and how/if that efficiency changes over time. Another key application of this network is a more recent development, to study the Australian and Southeast Asian tropical atmosphere.

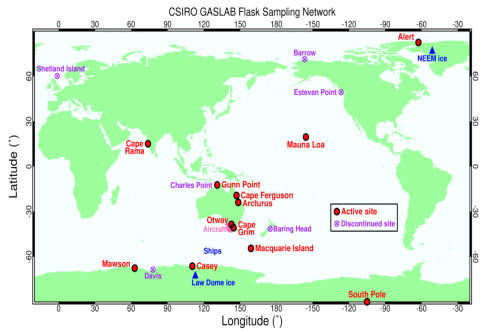

Figure 1. CAWCR/CSIRO GASLAB Flask Sampling Network (including in-situ programs at some sites)

Australian-Southeast Asia Regional Atmospheric Observation Network

There are limited atmospheric research programs operating in the Australian-Southeast Asian tropical region. Existing ground based atmospheric measurement sites operating in the Australian-Southeast Asian region are shown in Figure 2. There is also an expanding network currently being developed in India (Pondicherry and Port Blair).

The Total Carbon Column Observing System Network (TCCON) is a relatively new ground-based network of near-infrared Fourier Transform Spectrometers measuring GHG in the air column. TCCON is primarily for validating

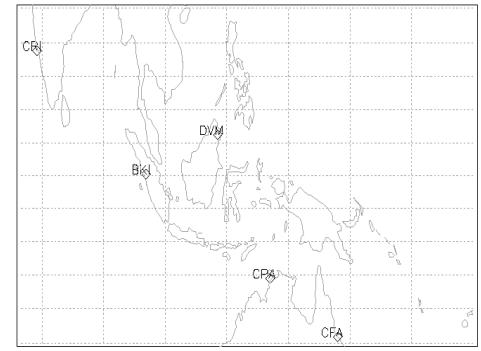

Figure 2. Australian/Southeast Asian tropical atmospheric research stations (CRI = Cape Rama, India; BKI = Bukit Koto Tabang, Indonesia, DVM = Danum Valley, Malaysia; CFA = Cape Ferguson, QLD, and GPA = Gunn Pt, NT)

remote sensing instruments (SCIAMACHY, GOSAT, OCO-version II) and to help constrain the global carbon budget. The only tropical station in this network is located at Darwin and has been in operation (University of Wollongong/Caltech) since September 2005.

Importance of the Tropical Atmosphere

The tropics play a major role in global climate through both natural and anthropogenic processes, of which many of these processes and potential associated feedbacks are poorly understood. Model representations of these processes, and the assessment of their magnitude and uncertainty, are inadequate and not well constrained. This is, in part due to insufficient, sparse (spatially and temporally) and sometimes uncertain observational data from vast regions of the tropics.

Approximately half of the global human population resides in the tropic regions, with a rapidly growing demand for energy (predominantly fossil fuel derived) and rapid land-use changes occurring. The tropics constitute about one third of the global land mass and is home to about 60-80% of the global biodiversity. Half of the global wetlands are in the tropics (Neue *et al.*, 1997), as are extensive biomes of tropical forest and savannas, which together contribute most of the terrestrial primary production of carbon (Field *et al.*, 1998).

The Australian-Southeast Asian tropics and the tropics globally, are regions expected to be sensitive to future climate change due to vulnerabilities in the large carbon pools of tropical vegetation (subjected to fire and/or deforestation) and draining of the tropical peatlands (Raupach and Canadell, 2008). Peatlands in Southeast Asia, predominantly in Indonesia, cover about 27 million hectares (Wetlands International, 2003 and 2004).

Southeast Asia in general is a major region of rapid development and economic growth (particularly southern China and India). How these tropical environments are transformed, and impacted by climate change and potential feedback processes, will play a major role in shaping the future global climate.

Globally, the tropics are significant source and sink regions for the major anthropogenic GHG CO_2, methane (CH_4), and nitrous oxide (N_2O) as well as other climatically-active constituents (aerosols, reactive gases, volatile organic compounds, hydroxyl radical, hydrogen etc). Estimates of global emissions of a range of atmospheric trace gases have large uncertainties due to a lack of measurements and understanding in tropical regions.

Biomass Burning

Globally, biomass burning is a major source of aerosols, CO_2, carbon monoxide (CO) and a range of other trace gases. Approximately 80% of global biomass burning occurs in the tropics, accounting for about 20% of the total global GHG emissions (mainly CO_2).

Biomass burning of tropical savannas is a globally significant feature of the carbon cycle and a source of a range of atmospheric trace gases (Cahoon *et al.*, 1992). Tropical savannas constitute about 12% of the global land area, and in Australia occupy about 25% of the continent, acting as an important carbon pool-approximately 30% of Australia's terrestrial carbon pool (Barrett, 2002). Up to about 10% of the

total global biomass burning occurs in the tropical savannas of Northern Australia alone (van der Werf, *et al.*, 2006). A large proportion of the landmass of the Northern Territory each year is exposed to regular seasonal biomass burning (prescribed burning and wild fires).

The 1997 El Niño event fires in Indonesia were estimated to have emitted the equivalent of 13-40% of the total annual global fossil fuel emissions (Page *et al.*, 2002). Southeast Asian peatland drainage accounts for approximately 5% of global CO_2 emissions.

Atmospheric Carbon Dioxide

Numerous global carbon-cycle modelling studies have been conducted, which have a tropical component, however, a common limitation with nearly all of these studies, is the lack of data in the global tropical regions. The international CO_2 modelling community have specified a requirement for "expansion of the CO_2 observation network within the tropics"to reduce uncertainties in regional estimates of CO_2sources and sinks using atmospheric transport models (Gurney *et al.*, 2006).

An inverse modelling study has shown that the introduction of a CO_2 observation site in the tropical Northwest Australian region would dramatically reduce (approximately 50%) the uncertainty of annual mean Australian CO_2 fluxes (Law *et al.*, 2004).

Atmospheric Methane

After a decade (1996-2006) of near zero global CH_4 growth in the atmosphere, it would appear there is a recent renewed growth rate of CH_4 (Rigby *et al.*, 2008), potentially attributed to increased growth in boreal and/or tropical (wetlands) sources or influences from a changing atmospheric sink (OH). The cause of these unexpected changes in CH_4 growth rate in the atmosphere continues to undergo considerable scientific debate. An inverse modelling study (Bousquet *et al.*, 2006) showed that the plateau in global atmospheric CH_4 concentrations was due to a reduction in wetland CH_4 emissions. Two recent studies (employing simple atmospheric mixing models) suggest conflicting explanations (Aydin *et al.*, and Kai *et al.*, 2011) for this behaviour. Using a method involving ice firn ethane measurements, Aydin *et al.*concluded their inferred pre-1980 fossil fuel based CH_4 emissions were double those of standard inventories, with a resultant 30% decrease in CH_4emissions post-1980,could account for the long term decline in CH_4 growth rate over the last 30 years. In contrast, the method employed by Kai *et al.*, using global (surface) isotopic measurements (^{13}C-CH_4 and ^{2}H-CH_4), indicated this behaviour was due to a decrease in microbial CH_4 sources in the northern hemisphere (primarily rice production) and that the isotopic data was not consistent with changes in fossil fuel CH_4 emission sources.

The inter-annual variability (IAV) in CH_4 emissions is dominated by tropical processes, in particular tropical wetlands (about 70% of global anomalies) in the order of +/- 12 Tg CH_4 yr^{-1} (Bousquet *et al.*, 2006). Biomass burning accounts for about 15% of the CH_4 IAV (Denman *et al.*, 2007).

The role of wetlands in global climate change is critical, because of the magnitude of the emissions and the potential for feedback from

the temperature dependence of wetland CH_4emissions. While some studies (Whiting and Chanton, 2001) suggest that wetlands could have a net reduction of anthropogenic warming, others (Shindell *et al.*, 2004) find that a doubling of atmospheric CO_2 would likely lead to an annual increase of 78% in CH_4 emissions from existing wetlands, largely in the tropics, leading to an atmospheric increase of 430nmol mol^{-1} CH_4 (~24%).

Termites are an additional natural source of CH_4, estimated to be in the range of 20-30 Tg yr^{-1} (Denman *et al.*, 2007). Termites, like wetlands, produce more CH_4 at higher temperatures and humidity (Becker, 1970). Two species of Australian savanna termites are particularly large CH_4 emitters, capable of greater than 7mg CH_4(kg termite biomass)$^{-1}$ hr^{-1} (Fraser *et al.*, 1986).

Atmospheric Nitrous Oxide

Globally, N_2O emissions are estimated to be 15 Tg (N) yr^{-1}, of which 80% is attributed to terrestrial sources and the remaining 20% from ocean sources (Huang *et al.*, 2008). The majority of these N_2O sources are from the tropics (80%), and the remaining from the mid-latitude regions (20%). Approximately 15% of the global N_2Osource is from the Southeast Asia (including China and Japan) region and 7% from South Asia.

The IPCC Third Assessment Report concluded that the tropical emissions had a large role in the observed global spatial concentration gradients of atmospheric N_2O (Forster *et al.*, 2007).

Recent *in-situ* surface to stratosphere measurements of N_2O conducted on the HIAPER Pole to Pole Observations campaigns (HIPPO) show high concentrations of N_2O in the tropics, predominantly in the middle and upper troposphere, indicating strong but very episodic tropical source events (Kort *et al,* 2011).

New Australian Tropical Atmospheric Research Facility

The establishment of an Australian tropical atmospheric research observatory would build on the extensive research infrastructure developed by the Bureau of Meteorology and the US Department of Energy Atmospheric Radiation Measurement (ARM) Program, in tropical Australia, which provides a background of extensive and long term cloud, thermodynamic and radiation measurements. This synergy would provide a unique opportunity to provide high quality aerosol and atmospheric composition measurements, leading to a greater understand of aerosol-cloud-climate interactions, a missing link in climate research. This combined research capability would enable atmospheric budget studies yet to be undertaken on a continuous, ongoing basis anywhere else in the tropics and would increase scientific understanding in three key areas:

1. address key uncertainties in aerosol-climate interactions and their implication for the hydrological cycle in the Australian tropics;
2. dramatically reduce the uncertainty in estimates of total greenhouse gas (GHG) emissions from Australia, and
3. provide key data on climatically active atmospheric constituents and their sources and sinks in the tropics in order to improve

our understanding of climate change forcing.

This would enhance the capability of Australia's coupled climate and earth system model - the Australian Community Climate and Earth-System Simulator (ACCESS) as well as providing valuable data for carbon-climate coupled model and satellite validation (SCIAMACHY[1], GOSAT[2], MOPITT[3]).

A pilot Australian tropical atmospheric research facility has recently (2010) been established at the Gunn Point Radar Facility (operated by the Australian Bureau of Meteorology) in Australia's Northern Territory (12.25S, 131.05E) (refer Figure 3). Figure 4 shows the view toward the west of the station as observed from the radar tower (coast is about 1-2 km across the surrounding savannah). The prevailing dry season meteorology at the Gunn Point site exposes the site to air masses derived predominantly from tropical northern Australia (northern Queensland and Northern Territory). Importantly these synoptic easterlies would entrain strong biomass burning signals from continental Australia(savannah). During the wet season (tropical monsoon), Gunn Point is exposed to air masses from the significant Southeast Asia GHG sources and sinks regions, including: the Timor Sea, Indonesian 'warm pool', Timor-Leste, Java, Sumatra, Borneo, and Malaysia.

Figure 3. Gunn Point (Northern Territory, Australia) radar facility with atmospheric chemistry module

Figure 4. View looking west from radar tower at Gunn Point site, Northern Territory

1) The SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY) [http://www.sciamachy.org/]

2) Greenhouse gases Observing SATellite (GOSAT) [http://www.gosat.nies.go.jp/index_e.html]

3) Measurements Of Pollution In The Troposphere (MOPITT) on NASA Terra Spacecraft

The current and proposed atmospheric measurement program for the tropical observatory at Gunn Point is shown in Table 1.

Table 1. Current and proposed atmospheric measurement program for Gunn Point station

Atmospheric species	Proposed analytical method	Research group	Operational
In-situ CO_2 & $^{13}CO_2/^{12}CO_2$	CRDS (Picarro)	CMAR	Yes
In-situ CH_4	CRDS (Picarro)	CMAR	Yes
In-situ CO/N_2O	CRDS	CMAR	2012
CO_2, $^{13}CO_2/^{12}CO_2$, $CO^{13}O$, CH_4, N_2O, H_2, CO	Flasks sampling (GC-FID, GC-ECD, MS), FTIR	CMAR/University of Wollongong	Yes
Short-lived halocarbons, C_4-C_{12} HCs	GC-ECD/FID/PDD	University of Cambridge, UK	2012
CFCs, HCFCs, HFCs, PFCs, SF_6, CH_3Br, CH_3Cl, CH_3I	GC-MS-Medusa	CMAR	2012/13?
Aerosols (AOD)	Nephelometer / Aeronet sun photometer. MAPP	CMAR	Campaign 2010
VOC	PTR-MS / automatic samplers	CMAR	2012/2013
O_3	ML9810, OZSU;	CMAR	Yes
CO	Trace Analytical	CMAR	Yes
NO/NO_x	Trace Analytical	CMAR	Yes
Particles ($PM_{2.5}$, PM_{10})	TEOM / HiVol	CMAR	2012/2013
Radon	ANSTO Radon Detector	ANSTO	Yes
OH radical (campaign)	FAGE	Leeds University, UK	2012/2013?

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INDONESIA (Bukit Kototabang)

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Figure 1. GAW Bukit Kototabang

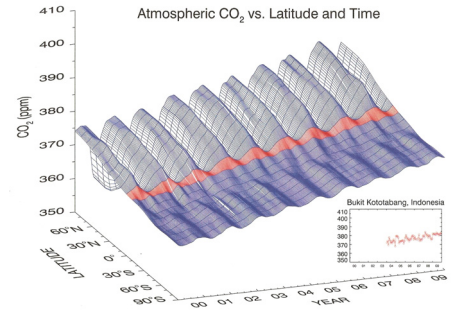

Figure 2. CO_2 concentration flying carpet (NOAA ESRL, 2010).

Global GAW Station Bukit Kototabang is a remote site, surrounded by tropical rainforest in the Island of Sumatra. Due to its position on the equatorial region, this site is affected by both of the earth's hemispheres. Greenhouse gases (GHGs) measurement in Bukit Kototabang has been started since 2004, as a part of Global Air Sampling Monitoring Network, conducted by NOAA Earth System Research Laboratory (ESRL). This measurement programme used air flask sampling method on weekly-basis sampling time. Four main GHGs are measured using this method: CO_2, CH_4, N_2O and SF_6. However, since March 2011, the programme has been temporary terminated.

For about 8 years of measurement, result shows that the concentration of all gases increases every year, with the only exception for CH_4 which indicates fluctuate concentration during the early years of measurement, but suggests a slight positive trend for the last four years. Seasonal variability is also observed for all gases due to different air mass trajectory headed toward the station (Nahas, 2010). CH_4 concentration has increased with the growth rate of ~2.69 ppb per year. However, in the last four years, CH_4 concentration has grown at the level of ~4.10 ppb per year. A study by Bousquet *et al.* (2011) using the wetland ecosystem emission model ORCHIDEE over the period 2006-2008 has found that tropical natural wetlands are a dominant contributor to the increasing trend of CH_4 concentration. Meanwhile, CO_2 concentration measured in Bukit Kototabang during the period 2004-2010 has grown at the rate of ~1.50 ppm per year. A CO_2 concentration profile depicted in Figure 2 shows that CO_2 concentration in the equatorial region (marked as red) is in between the two hemispheres, with large concentration

variability observed in the Northern Hemisphere, while relatively homogenous concentration in the South. A similar increase is also found on N_2O and SF_6 with these two gases have ~0.68 ppb and ~0.23 ppt of annual growth rate, respectively.

For ensuring the data continuity and also for having a better data resolution, a continuous monitoring instrument, Picarro Model G1301, has been installed in Bukit Kototabang on October 2008. However, the initial operation of this instrument was without proper calibration. It was until late 2009, the calibrator unit, along with NOAA standards gases, was installed to ensure the data quality by providing calibration. The installation of calibrator unit was funded by MeteoSwiss and performed by Empa, Switzerland. After having instrument failure for several months, the instrument was fully operated again since March 2011 with a relatively good performance. In addition, a recent system and performance audit by Empa in the early November 2011 has provided additional working standard gases to equip the measurement.

Picarro G1301 measures three GHGs components: CO_2 and CH_4 (reported in ppm) and H_2O (% v/v). Six different air intakes are used in the measurement process, they are ambient air intake for three different levels and the remaining three intakes are for standard gases. Intakes from ambient air are taken from inlets located at 10 m, 20 m and 32 m above the ground. Calibrator unit controls which air intake taken to the instrument by automatically switching the valves that regulate which air or gas is being sampled. Before entering the instrument, the air and gas are dried to remove the water vapour content. H_2O concentration is kept at ~0.05% v/v and therefore in this measurement scheme, H_2O concentration in ambient air is not taking into account.

Figure 3 illustrates the diurnal variation of CO_2 and CH_4 concentration over the period April-October 2011. Result shows that three inlet levels give different response to the gases measurement, particularly during the night time. The top level inlet measures a considerably smaller amount of CO_2 and CH_4, compared to the two lower inlets. It is very likely due to vegetation respiration which occurs during the nighttime and gives a stronger influence to the air taken from 10 m and 20 m. At the height of 10 m, gas concentration are measured at the highest point because this level is affected more by surface influences.

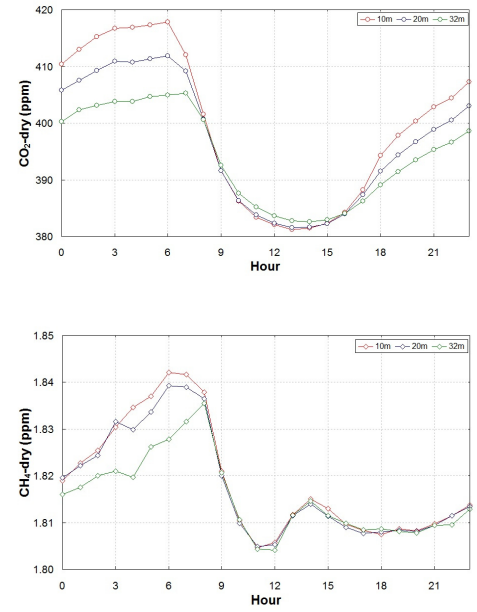

Figure 3. Diurnal variation (in local time) of CO_2 and CH_4 concentration in Bukit Kototabang

Table 1. CO_2 and CH_4 concentration variation between day and night time at there different inlets.

Inlet (m)	CO_2 (ppm)			CH_4 (ppb)		
	Day	Night	Difference	Day	Night	Difference
10	391.3	409.3	18.0	1817.6	1820.1	2.5
20	390.3	404.5	14.2	1816.6	1819.3	2.7
32	389.8	399.4	9.6	1815.3	1815.3	0

A different trend is observed in the daytime when CO_2 and CH_4 concentration are very similar for all ambient air intakes, with a slight tendency of air intake from 32 m is having the highest CO_2 concentration, particularly between 9 am to 3 pm. However, there is a significant response of CH_4 concentration during the daytime. A small increase is observed in this period, started from 12 pm until around 3 pm.

To sum up, GHGs measurement result in Bukit Kototabang offers a perspective for the trend in the equatorial region. Influences from both hemispheres affect the seasonal variability of GHGs concentration. The ongoing measurement has enabled a diurnal monitoring for CO_2 and CH_4. Result has indicated the concentration variability for three different inlets with strong surface influences for the lower inlets. GHGs monitoring in Bukit Kototabang should be continued and maintained to provide important data, especially for the equatorial area where a large data gap is exist.

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JAPAN

Scale for greenhouse gas observation and Intercomparison activities in JMA

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The Activities of WCC for Methane

Under the WMO GAW programme, the Japan Meteorological Agency (JMA) has served as the GAW World Calibration Centre (WCC) for methane (CH_4) in Asia and the South-West Pacific since 2001. The activities of this centre include maintaining the CH_4 standard gases which is traceable with the WMO scale maintained by National Oceanic and Atmospheric Administration (NOAA), making calibration at the request of GAW participating organizations in the region, and organizing the CH_4 reference gas intercomparison experiments.

The purpose of the intercomparison is to ascertain to what extent the current practiceof calibration is working, and eventually to ensure that the measurementsare intercomparable. In the CH_4 reference gas intercomparison experiments, two cylinders containing different CH_4 concentrations are circulated in the GAW community and other co-operative observation institutions in Australia, China, Japan, New Zealand and the Republic of Korea. JMA also circulates the same cylinders through the laboratories in Japan, Tohoku University (TU) and National Institute for Environmental Studies (NIES) (Figure 1.) At the beginning and the end of the circulation, JMA measures the cylinders to check a possibledrift during the circulation.

The intercomparison has been carried out repeatedly since 2001. The 3rd CH_4 reference gas intercomparison for the South-West Pacific region was carried out through 2010 and 2011, and the 4th intercomparison for Asia region started in 2011. JMA collects the measurement results from each laboratory and disseminates compiled results back to the participants. The differences between the participants were smaller in recent years than previous intercomparisons since WMO CH_4 scale was commonly used in the GAW community (Figure 2).

The results of the intercomparison are reported to WMO to be shared within the GAW community. The details of the intercomparison results and contact information at each laboratory are available at the website of WCC for CH_4 (Figure 3). To fulfill the responsibility of WCC, JMA will continue to organize the intercomparison experiment. We will appreciate continued cooperation of the regular participants and encourage other laboratories in the region to participate in.

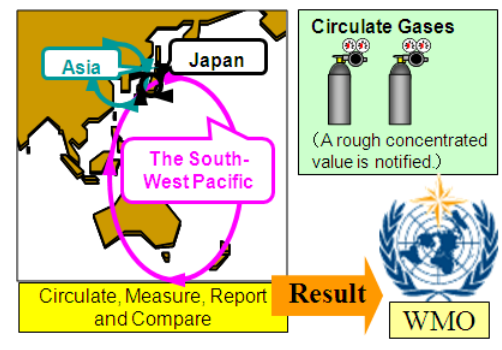


Figure1. CH_4 Reference Gas Intercomparison

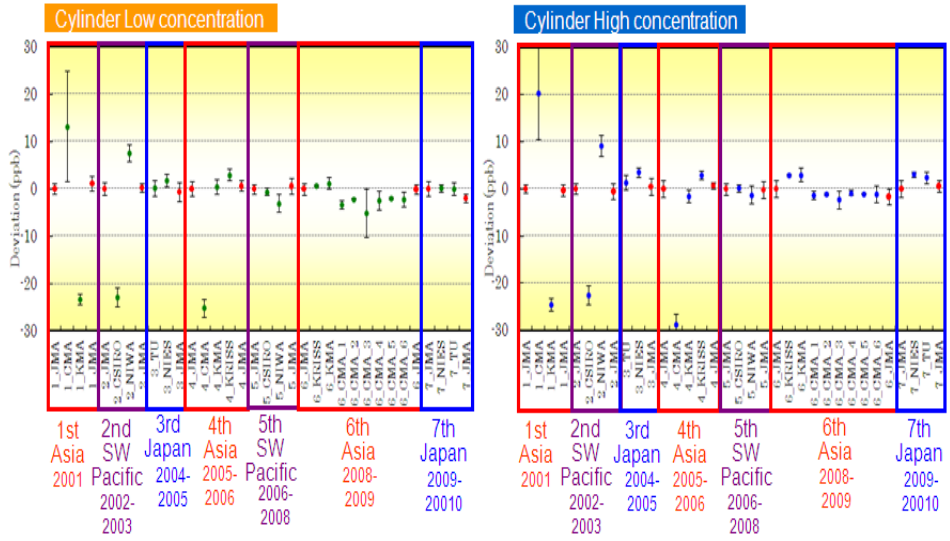
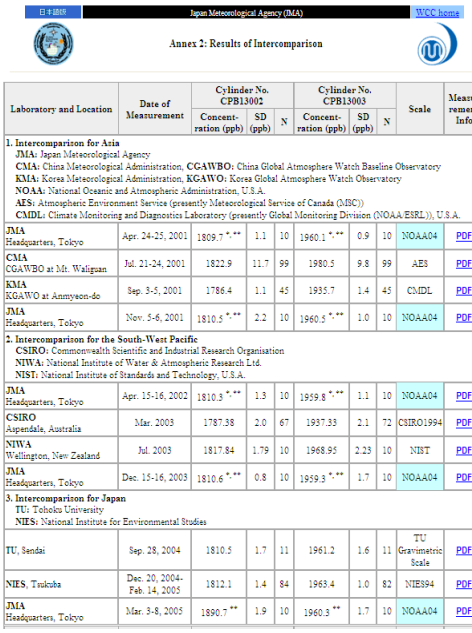


Figure 2. The results of CH_4 reference gas intercomparison (from 1st to 7th), Difference from JMA at the beginning of circulation (JMA results are marked with red symbols)



Annex 2: Results of Intercomparison

Laboratory and Location	Date of Measurement	Cylinder No. CPB13002 Concentration (ppb)	SD (ppb)	N	Cylinder No. CPB13003 Concentration (ppb)	SD (ppb)	N	Scale	Measurement Info
1. Intercomparison for Asia **JMA:** Japan Meteorological Agency **CMA:** China Meteorological Administration, **CGAWBO:** China Global Atmosphere Watch Baseline Observatory **KMA:** Korea Meteorological Administration, **KGAWO:** Korea Global Atmosphere Watch Observatory **NOAA:** National Oceanic and Atmospheric Administration, U.S.A. **AES:** Atmospheric Environment Service (presently Meteorological Service of Canada (MSC)) **CMDL:** Climate Monitoring and Diagnostics Laboratory (presently Global Monitoring Division (NOAA/ESRL)), U.S.A.									
JMA Headquarters, Tokyo	Apr. 24-25, 2001	1809.7 *,**	1.1	10	1960.1 *,**	0.9	10	NOAA04	PDF
CMA CGAWBO at Mt. Waliguan	Jul. 21-24, 2001	1822.9	11.7	99	1980.5	9.8	99	AES	PDF
KMA KGAWO at Anmyeon-do	Sep. 3-5, 2001	1786.4	1.1	45	1935.7	1.4	45	CMDL	PDF
JMA Headquarters, Tokyo	Nov. 5-6, 2001	1810.5 *,**	2.2	10	1960.5 *,**	1.0	10	NOAA04	PDF
2. Intercomparison for the South-West Pacific **CSIRO:** Commonwealth Scientific and Industrial Research Organisation **NIWA:** National Institute of Water & Atmospheric Research Ltd. **NIST:** National Institute of Standards and Technology, U.S.A.									
JMA Headquarters, Tokyo	Apr. 15-16, 2002	1810.3 *,**	1.3	10	1959.8 *,**	1.1	10	NOAA04	PDF
CSIRO Aspendale, Australia	Mar. 2003	1787.38	2.0	67	1937.33	2.1	72	CSIRO1994	PDF
NIWA Wellington, New Zealand	Jul. 2003	1817.84	1.79	10	1968.95	2.23	10	NIST	PDF
JMA Headquarters, Tokyo	Dec. 15-16, 2003	1810.6 *,**	0.8	10	1959.3 *,**	1.7	10	NOAA04	PDF
3. Intercomparison for Japan **TU:** Tohoku University **NIES:** National Institute for Environmental Studies									
TU, Sendai	Sep. 28, 2004	1810.5	1.7	11	1961.2	1.6	11	TU Gravimetric Scale	PDF
NIES, Tsukuba	Dec. 20, 2004-Feb. 14, 2005	1812.1	1.4	84	1963.4	1.0	82	NIES94	PDF
JMA Headquarters, Tokyo	Mar. 3-8, 2005	1890.7 **	1.9	10	1960.3 **	1.7	10	NOAA04	PDF

Figure 3. Website of WCC for CH_4 (http://gaw.kishou.go.jp/wcc/wcc.html)

The JMA's operational Calibration System for Greenhouse Gases

In order to ensure traceability to GAW international standards and maintain the accuracy of the measurements, JMA standards for carbon dioxide (CO_2), CH_4, carbon monoxide (CO), nitrous oxide (N_2O) and surface ozone (O_3) have adopted WMO scale through regular calibrations at the WMO Central Calibration Laboratory (CCLs). JMA has its own calibration systems for CO_2, CH_4, N_2O, CO and O_3. These systems are operated at our laboratory in the JMA Headquarters in Tokyo. Taking CO_2 as an example, JMA has three ranks (primary, secondary and working) of standard gases. First, primary standards are calibrated with WMO scale at NOAA Earth System Research Laboratory (ESRL). Then secondary standards are calibrated with the primary standards in the effort to conserve the primary gases. Finally, working standards are calibrated with the secondary standards, and provided for various observation programs (stations, ships and aircraft) in JMA. Therefore, JMA's measurements keep traceability to WMO scales by using these calibration systems.

On the other hand, laboratories in Japan other than JMA maintain their own scale for measurements of greenhouse gases. Taking the opportunity of the WMO world trace gas intercomparison during 2009 and 2010, the five gases cylinders which consist of three WMO reference gases and additional two JMA CO_2 standard gases, were circulated among each laboratory in Japan (Figure 4).

This circulation enabled the laboratories to compare measurement data of their individual scale. We aim to build a systematic intercomparison framework of standard scales among laboratories in Japan and to maintain stability of standard scale over the long term.

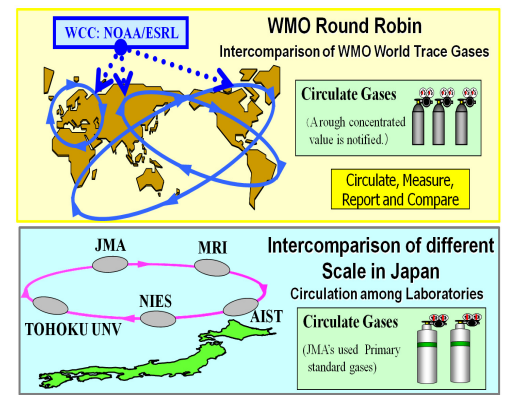


Figure 4. CO_2 Inter-laboratory Comparison Experiments (Top: Global, Bottom: Japan)

KOREA (Anmyeon-do)

Han-Cheol Lim *(Korea Meteorological Administration)*

Anmyeon-do (36°32'N, 126°19'E; 45.7 m above mean sea level) is a regional GAW station located on the west coast of the Korean Peninsula (Figure 1). The observatory has been operated by the Korea Global Atmosphere Watch Center (KGAWC) of KMA since 1996, and presently, 36 parameters, including greenhouse gases, aerosols, ultraviolet radiation, ozone, and precipitation chemistry, are being measured.

The Center is actively engaged in international activities, such as participating in intercomparison experiment of greenhouse gases, 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.

Since 1999, the Center has been monitoring major greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFC-11, CFC-12). In 2007, the number of GHGs monitored at the Center was increased to seven, with the addition of chlorofluorocarbon (CFC-113) and sulfur hexafluoride (SF_6). Figure 2 shows the concentration levels for the five GHG species observed at Anmyeon-do from 1999 to 2010, along with the NOAA/GMD global CO_2 concentration trends. The CO_2 concentrations at Anmyeon-do are substantially higher than the global average and the N_2O concentrations are steadily increasing, while CFCs exhibit a continuously declining trend.

The average CO_2 concentration for the year 2010 recorded 394.5 ppm, an increase of 23.8 ppm (6.4%) relative to the annual average of 370.7 ppm for 1999, and 5.9 ppm higher than the global average of 388.6 ppm for the same year as documented by NOAA/GMD. The annual

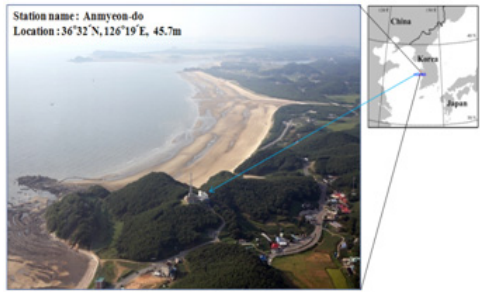


Figure 1. The Korea Global Atmosphere Watch Center is located at the relatively unpolluted western coastal area.

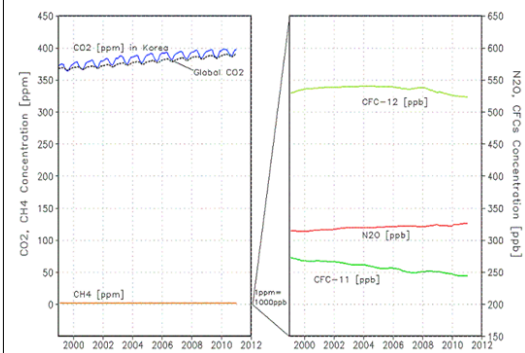


Figure 2. Annual averages of GHGs(CO_2, CH_4, N_2O, CFCs) concentration for 1999-2010.

Table 1. Average concentrations for 2010 and annual mean growth rates for the 12-year period from 1999 through 2010 of major GHGs in the background atmosphere of the Korean Peninsula.

GHGs	CO_2	CH_4	N_2O	CFC-11	CFC-12
Average concentrations in 2010	394.5 (ppm)	1.914 (ppm)	325.2 (ppb)	244.7 (ppt)	524.2 (ppt)
12-year avg. growth rates	+2.12 (ppm/year)	+0.00320 (ppm/year)	+0.96 (ppb/year)	-2.30 (ppt/year)	-0.84 (ppt/year)

growth rate of CO_2 for the 12-year period from 1999 through 2010 was 2.12 ppm/year, higher than the global average of 1.9 ppm/year, however ithas slowed in recent years. Table 1 summarizes the 12-year averaged annual growth rates and 2010 annual average concentrations of GHGs in Anmyeon-do.

KGAWC held the 3rd Asian GAW Workshop on Greenhouse Gases in Seoul, Korea on September 2011. GAW station members coming from six countries participated in the workshop to present results of long-term monitoring of GHGs observed in each country and to discuss about Asian GAW issues. And also, there were some invited addresses by SAGs and CCL of WMO/GAW for introducing recent activities of WMO/CCL as well as exchanging of measuring techniques and new information. Furthermore, one of the significant results in the workshop is that the establishment of the *Asian GAW Greenhouse Gases Working Group* which covers both Asian (RA2) and South and west Pacific (RA4). The contact person in each country is also decided. English version of the 'Summary of Korea Global Atmosphere Watch 2010 Report' is published in September 2011 (Figure 3, right).

Figure 3. The 3rd Asian GAW Workshop on Greenhouse Gases was held in Seoul, Korea (the left) and Summary report published by KGAWC in 2011 (the right).

KGAWC serves dangerous CO_2 concentration levels with easy visualization graphic style to the general public through KMA web (called Climate Change Information Center). Dangerous CO_2 concentration level is defined by CO_2 concentrations greater than 450 ppm as suggested by many previously published papers. Carbon dioxide concentration levels are divided into three stages in the graphic display: (1) Dangerous stage (420-450 ppm); (2) Notice stage (380-420 ppm); (2) Recognition stage (280-380 ppm). So, people can easily look at the increasing trend of carbon dioxide concentration in Korea, and they can get information regarding when and how long does it take to reach at dangerous stage (Figure 4).

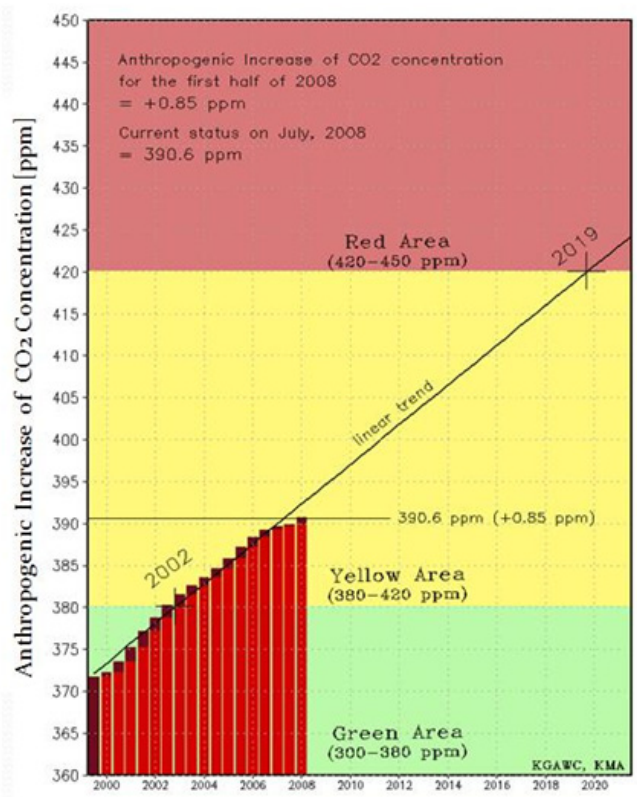


Figure 4. Assessment and long-term monitoring of the anthropogenic increase of CO_2 concentration. It is to provide any climate information on increase of Carbon dioxides observed in Anmyeon-do station to user.

KOREA (King Sejong)

Taejin Choi *(Korea Polar Research Institute)*

Polar regions are important in past, present and future global climate processes in terms of global energy, water and thermohalic circulation. In addition, they are ideal platforms for monitoring background greenhouse gas concentrations. Monitoring accurate levels of atmospheric greenhouse gasat polar regions are important in several aspects; accurate quantification of background greenhouse gas concentrations and their increasing rate at present, better understanding of past climate based on gases in the ice cores and evaluation of greenhouse gas sinks or sources of areas with lack of measurements based on precision concentration measurements at some locations and inverse methods. The Southern Ocean is known as a strong sink for atmospheric CO_2. However, atmospheric CO_2 uptake by the Southern Ocean has been decreased recently (e.g., Le Quéré, *et al*, 2007, Lenton and Matear, 2007). To reduce large uncertainties in the global carbon budget and hence in the predicted response to climate change related with the Southern Ocean CO_2 process, additional long term measurements are needed at areas with lack of measurements. Korea Polar Research Institute (KOPRI) is an international polar research institute operating the Antarctic King Sejong Station (62°13′S, 58°47′W), the Arctic Dasan Station (78° 55′N, 11° 56′E) and the Ice-Breaking Research Vessel, Araon. In addition, its 2nd Antarctic station, Jang Bogo station (74° 36′S, 164° 13′E) will be open in 2014. The King Sejong station is located near the Antarctic Peninsula, which is one of the regions experiencing the rapid warming and environmental change. The Jang Bogo station is located on Terra Nova Bay, Northern Victoria Land, where is the border of stratospheric ozone hole and the warming area on Antarctica. The Ice-breaker, Araon cruses along West Antarctica between the King Sejong station and the Jang Bogo station for research and logistics (Fig. 1). At the Arctic sea, on board measurements can be made at higher latitude than those at the stations on Siberia, Alaska and Canada due to the melting of sea ice on boreal summer seasons. All of these research infra structure are unique for the study on climate change at polar regions through research programs such as

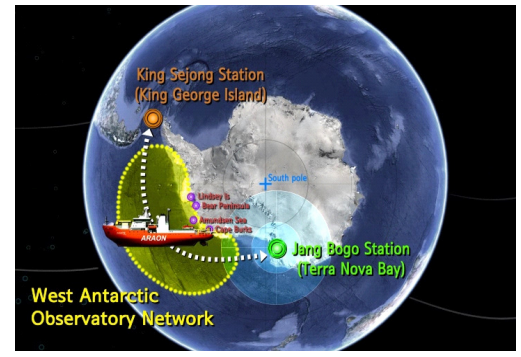


Figure 1. Greenhouse gasmonitoring area at the Antarctic by KOPRI. The King Sejong station (Antarctic Peninsula), Jang Bogo station (Northern Victoria Land) and the Ice Breaking Research Vessel, Araon (the Pacific Sector of Antarctica)

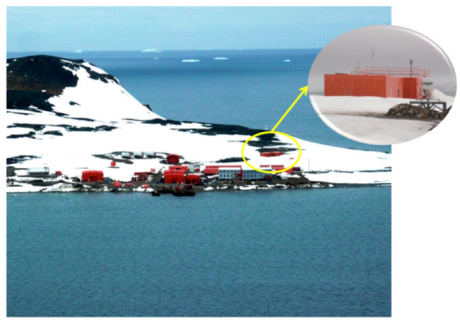


Figure 2. The Antarctic King Sejong station and the observatory building for CO_2 and other trace gas concentration measurements

GAW. As a first step, KOPRI registered its first Antarctic station, the King Sejong station, as a GAW regional station together with Korea Meteorological Administration (KMA) in 2010. For background CO_2 concentration measurement, a cavity ring-down spectroscopy (CRDS) analyzer (G1200, Picarro, Inc., USA) was installed in an observatory building at the King Sejong Station in December of 2009 (Fig. 2). The measurement system consists of inlet outside the observatory building, a diaphrame pump, dual dehumidifier, a mass flow controller and the CRDS. Sampled air moves from the inlet to the CRDSthrough decarbon tube with a diameter of 3/8". The inlet height is 6 m above the surface ground. Flow rate into the CRDS is controlled 250 ml min^{-1} by the mass flow controller. Water vapor concentration in the sampled air is minimized to be held below 0.1 %. CO_2 concentration data are recorded at an interval of 1 ~ 2 seconds and they are averaged over 10 minutes for further analysis. Wind direction and black carbon mass concentration are used to filter out possible contaminated air sample due to the power plant and other sources in the station. Two levels of standard CO_2 (361.68 ± 0.2 ppm, 383.69 ± 0.2 ppm) are measured at aninterval of 15-day to monitor the drift of the instrument with time. The instrument is calibrated with new coefficients when the concentration is different from standard gas concentration over 0.1 ppm. Figure 3 shows the variation of monthly-averaged CO_2 concentration in 2010. It ranged from 384.30 (± 0.32) ppm in February to 387.93 (± 0.17) ppm in October. There are two characteristics in the annual variation of CO_2 concentration. One is that the difference between the maximum value and the minimum one was 3.63 ppm, a relative high difference. Based on the CO_2 data at the Jubany station ~ 6 km away from the King Sejong station, the difference was less than 3.0 ppm except for 3.58 in 2005. Second one is that the CO_2 concentration in February was lower than one in January. To understand the annual variation of CO_2 including low CO_2 concentration at the site, further analysis are in progress such as the investigation on chlorophyll concentration sampled near the station together with other supplementary data.

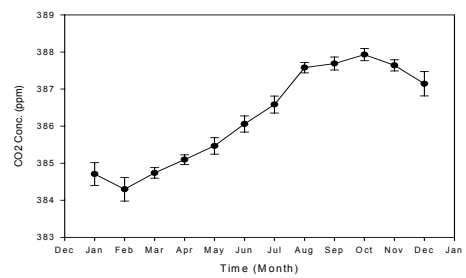


Figure 3. Monthly averaged CO_2 concentration at the King Sejong station in 2010. Error bar indicates the standard deviation.

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MALAYSIA

THE GLOBAL ATMOSPHERE WATCH (GAW) ACTIVITIES IN MALAYSIA

Maznorizan Mohamad and Toh Ying Ying *(Malaysian Meteorological Department)*

In order to support the Global Atmosphere Watch (GAW) Programme of World Meteorological Organization (WMO) as well as to contribute to the national and international community, Malaysian Meteorological Department (METMalaysia) has since established GAW stations to carry out systematic monitoring of atmospheric constituents in response to acquire a high quality data to studyand understand the regional issues of trans-boundary haze, acid deposition, climate variability, climate change and stratospheric ozone depletion.

METMalaysia has participated in the worldwide network of GAW since 1998 and will continue to play an active role in this international network in many more years to come. There are presently 3 GAW monitoring stations operated by METMalaysia;

i. Regional GAW station

Located in Petaling Jaya in METMalaysia Headquarters at Lat: 03°06'N, Long: 101° 39'E
Height above MSL: 87m.
It's an urban site and started operating in April 1998.

Figure 1. Regional GAW Station in Petaling Jaya

ii. Regional GAW Station

Located in Cameron Highlands at Lat: 04°28'N, Long: 101°23'E
Height above MSL: 1545 m
It's a developing rural site and started operating in early 1999.

Figure 2. Regional GAW Station in Cameron Highlands

iii. Baseline/ Global GAW Station

Located in Danum Valley Sabah at Lat: 04° 59'N, Long: 117°51'E
Height above MSL: 427 m
It's a remote site in pristine tropical rain forest and started operating in 2004.

Figure 3. The Danum Valley Global GAW Station is located in Pristine Forest, Sabah

Figure 4. Global GAW Station in Danum Valley

Since November 2003, METMalaysia has established a baseline or global GAW station in Danum Valley, Sabah, located at the northeastern part of Borneo. Danum Valley is one of the best-known research sites in tropical rainforests in the world. The GAW station located within Class 1 forest conservation area which offers an ideal location for investigating atmospheric-biosphere interactions in tropical rainforest environment, study of long-range transport of pollutants and ability of forests to act as sinks for atmospheric pollutants. The station is the second of its kind in Southeast Asia after one in Kototabang, Sumatra and 23rd such centre worldwide, provides with reliable high-quality data and information on atmospheric environment. The station consists of a laboratory, office, meeting room, rooftop platform and 100 meter sampling tower which is the highest point in Danum Valley.

The Measurement Programme at Danum Valley GAW Station

The Danum Valley GAW station with a complete and comprehensive monitoring programme is actively engaged in the local and international collaboration and activities with regard to the atmospheric composition monitoring campaign. The monitoring programmes at Danum Valley GAW station are data gathering for parameters such as rainwater chemical composition, physical and chemical properties of aerosol, greenhouse gases (GHGs), reactive gases and meteorological parameters.

The measurement started in 2004, and because of its relatively pollution free environment, Danum Valley GAW station is considered as one of the ideal site for baseline measurement of the atmospheric composition as well as geographically representative of the background atmosphere of the maritime southeast Asia and the equatorial region.

There are several instruments installed at the GAW station and among those are Wet-Only Sampler, Filter Pack, Passive Sampler, LoFlo Mark II CO_2 Analyzer, Ozone Analyzer, Tapered Element Oscillating Microbalance (TEOM), Nephelometer, Multi Angle Absorption Photometer (MAAP), Precision Filter Radiometer (PFR), Persistent Organic Pollutants (POPs) PUF Disk Sampler, Flask Sampling and Automatic Weather System (AWS).

The following are some of the analysis of parameters measured using LoFlo, ozone analyzer and flask sampling.

i) Reactive Gases

Reactive gases such as SO_2, NOx, NH_3, O_3, H_2S, CO, VOC, H_2SO_4 and HNO_3 of dry deposition ofatmospheric pollutants remain an elusive contribution to the total deposition of pollutants from the air to surface. There are several methods that have been engaged to measure gaseous concentrations in Danum Valley namely ozone analyzer, filter pack and passive sampler.

Surface ozone plays an important role in physical, chemical and radiative process in the troposphere and has significantly influenced the formation of photochemical smog that has an effect on both biota and human health. The measurement of surface ozone in Danum Valley using the THERMO 49i UV Ozone Analyzer is therefore important to characterize its global background distribution and at the same time METMalaysia is collaborating with National Institute of Environmental Studies (NIES), Japan

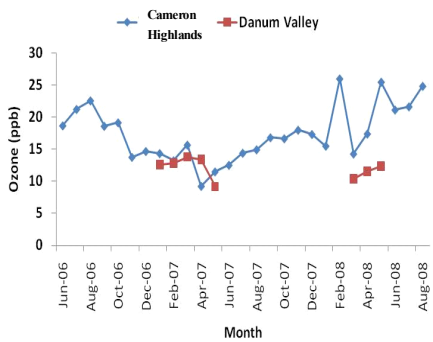

Figure 5. The Monthly Mean O_3 at Danum Valley and Cameron Highland

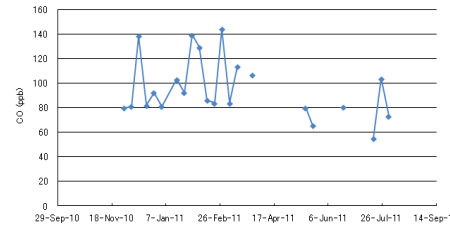

Figure 6. The CO Concentrations at Danum Valley GAW Station (Nov 2010 – July 2011)

using Flask Sampling to measure the CO concentrations.

The analysis of the monthly mean ozone concentrations in Figure 5 have shown that theozone remained below 15ppb in Danum Valley and ranged between 9 to 26 ppb in Cameron Highlands. Whereas, the CO concentrations ranged between 55 to 143 ppb (refer Figure 6).

ii) Greenhouse gas

In Danum Valley, CO_2 concentrations are measured continuously using CSIRO LoFlo Mark II Carbon Dioxide Analyzer and automatic Flask Sampling.

Figure 7 and 8 showed time series of hourly mean CO_2 and the comparison of CO_2 concentrations using LoFlo analyzer and flask sampling respectively. The range of the hourly mean is between 386 - 396 ppm (Jan) and 385 - 399 ppm (July), whereas for the two different instruments, the value is ranged between 385 – 400 ppm. Currently only CO_2 data from Loflo analyzer is submitted to the World Data Centre for GHGs (WDCGG) at Japan Meteorological Agency.

Similarly with CO and in collaboration with NIES, GHGs such as CH_4, N_2O and SF_6 are measured using flask sampling starting from November 2010.

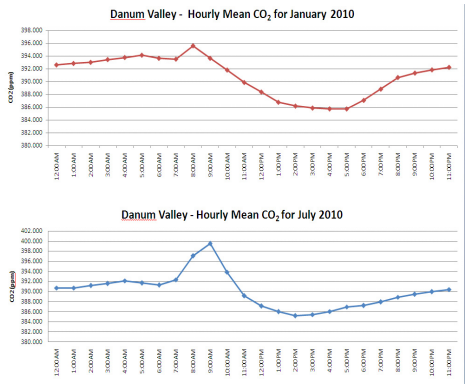

Figure 7. The Time Series of Hourly Mean CO_2 at Danum Valley GAW Station

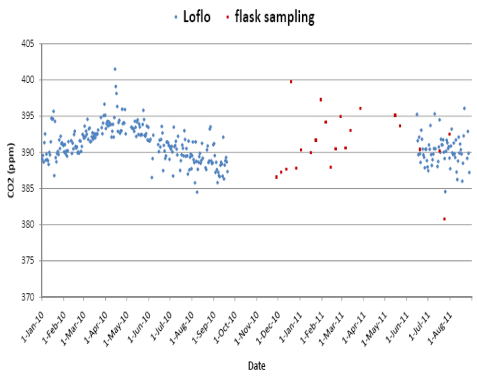

Figure 8. The Comparison of CO_2 concentrations using LoFlo Analyzer and Flask Sampling

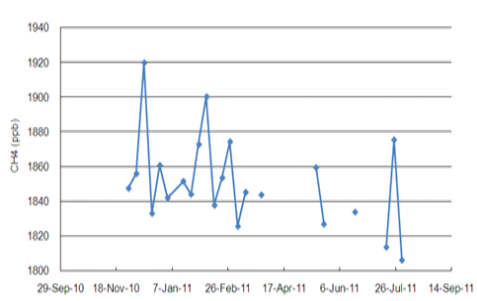

Figure 9. The CH_4 concentrations at Danum Valley GAW Station (Nov 2010 – July 2011)

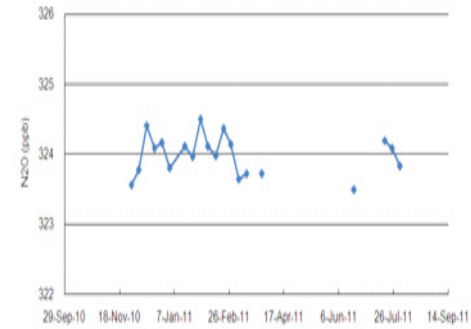

Figure 10. The N_2O concentrations at Danum Valley GAW Station (Nov 2010 – July 2011)

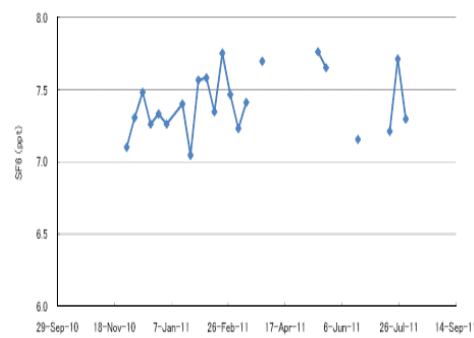

Figure 11. The SF_6 concentrations at Danum Valley GAW Station (Nov 2010 – July 2011)

Figure 9, 10 and 11 showed the time series analysis of CH_4, N_2O and SF_6. The concentrations of these three GHG (CO_2, CH_4, N_2O) and SF_6 are comparable with the range of the global average values as issued by the 2009 WMO-GAW Greenhouse Bulletin.

It is known that these three major GHGs are closely linked to anthropogenic activities and have strong interactions with the biosphere and the oceans. This is agreeable with the locality of GAW Station in Danum Valley which is in the pristine tropical forest and about 50 km from the coast.

Collaboration

Since the Danum Valley GAW station started operatingin 2004, METMalaysia has embarked in several collaboration with international research institutes and among those collaboration programmes are as follows:-

i. The National Institute of Environmental Studies, Japan
   Flask Sampling to measures greenhouse gases and reactive gases.
ii. The International data Sharing and data provider to the WMO World Data Centre (WDCGG) for the GHGs with Japan Meteorological Agency (JMA).
iii. The twinning programme with the World Calibration Centre for physical aerosol properties which is hosted by the Institute for Tropospheric Research, Germany has been ongoing since 2006. The collaboration is focused on the measurement of the aerosol physical properties including the aerosol scattering and absorption coefficient.
iv. The collaboration with the Environment Canada on the Global Atmosphere Passive Sampling (GAPS) programme started in 2005. Danum Valley GAW station is part of the sampling network with approximately 65 sites on seven continents that was established to investigate air concentrations of persistent organic pollutant (POPs).
v. The EANET Activities
   The Danum Valley GAW Station is one of the 46 stations, participated in Acid Deposition Monitoring Network in East Asia (EANET) that focused on investigating the state of acid deposition problem in East Asia. The Danum Valley GAW station will continue participating in this network as to make sure that the atmosphere of this pristineforest is closely monitored for any acidic species that threaten its air quality.
vi. The Oxidant and Particle Photochemical processes above South-East Asian tropical Rain Forest (OP3) campaign is a three year scientific research project (Oct. 2007 – Sept. 2010) with the objective to understand how emissions of reactive trace gases from tropical rain forest mediate the regional scale production and processing of oxidant and particles, and to better understand the impact of these processes on local, regional and global scale atmospheric composition, chemistry and climate. The consortium of this project include the UK universities, METMalaysia, University Malaysia Sabah and Sabah Foundation
vii. The collaboration with CSIRO, Australia started with the installation of LoFlo Mark II to measure the CO_2 concentrations in the pristine forest of Sabah. The CO_2 data set is analyzed to study the pattern of CO_2 in forested area in Southeast Asia.
viii. The collaboration with World Radiation Centre, Davos Switzerland regarding the AOD monitoring using Precision Filter Radiometer (PFR). This collaboration started in 2007 and is still on-going. The objective of this collaboration is to measure the atmospheric AOD through the vertical column of atmosphere over the

equatorial region of Maritime Southeast Asia.

Future Direction

The GAW Danum Valley is able to provide good infrastructure for the research activities focussing on the environment, air quality and atmospheric composition as well as climate. As such MET Malaysiais always welcome any institution to participate and collaborate with us with the objective of doing an extensive and significant research work and subsequently produce research findings that will be beneficial to both parties and the world community as a whole.

Reference

OP3-Danum-08, 2007. Oxidant and particle photochemical processes above a South-East Asian tropical rain forest

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