# Current Status and Challenges of Greenhouse Gas Observation and Data Utilization

Japan's Contribution to the Paris Agreement

Task Team on the International Initiatives towards Promotion of Greenhouse Gas Observation

Office for Coordination of Climate Change Observation (OCCCO)

# Current Status and Challenges of Greenhouse Gas Observation and Data Utilization

Japan's Contribution to the Paris Agreement

The Paris Agreement established a long-term goal of keeping the global average temperature well below 2 °C above the pre-industrial level by achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHGs) in the second half of this century.

To monitor and evaluate the impacts of climate change measures for implementing the Paris Agreement, accurate knowledge of emission trends and reliable GHG inventories are essential. Emission reporting from developing countries is particularly important.

There has been an increase in the number of observational platforms, such as satellites, aircraft, ships, and ground stations, for monitoring the concentrations of atmospheric GHGs and their surface fluxes. National and regional inventories of emissions have also been prepared at higher spatial and temporal resolutions.

The reliability of evaluations of natural and anthropogenic sources and sinks has also been improved in recent years by combining data regarding sources and sinks with advanced analysis systems such as "top-down" (with atmospheric observations and inverse modeling) and "flux upscaling" (with surface flux/emission network data and upscaling) methods.

Estimating emissions based on Earth observations for GHGs has enormous potential for providing additional sources of information that can complement national inventories. In particular, emissions from expanding megacities, intermittent emissions from agricultural fields and forest (peat) fires, and emissions from large-scale land-use change are essential targets.

Relevant Japanese institutions and agencies for GHG observation and analysis will cooperate to improve up-to-date analysis systems and data coverage in Asia–Oceania for better estimation of emission distributions with sufficient accuracy, and to provide the data and knowledge to stakeholders in time with the Global Stocktake Process under the Paris Agreement for verification of impacts of mitigation actions.

### **Ground-based Monitoring**

#### Atmospheric concentrations of GHGs at near-ground levels



In 1987, Japan Meteorological Agency (JMA) started monitoring of CO2 at Ryori for the first time in Japan as a GAW Regional Station. Observation of GHGs started successively also at Minamitorishima (GAW Global Station) and Yonagunijima (GAW Regional Station). The datasets are provided through the World Data Centre for Greenhouse Gases (WDCGG) (see page 7).



Yonagunijima

Minamitorishima

The National Institute for Environmental Studies (NIES) conducts monitoring of the atmospheric GHGs such as CO<sub>2</sub> at Cape Ochiishi, Hokkaido, Hateruma Island, Okinawa, and the summit of Mt. Fuji. NIES analyzes the variations in mixing

ratios and isotope ratios of GHGs and other related atmospheric species, and provide monitoring data on its website (http://db.cger.nies.go.jp/portal/) and on WDCGG.





Monitoring station, Cape Ochiishi

Monitoring station, Hateruma



Mt. Fuji automated weather station



Annual variations in CO<sub>2</sub> concentration

#### Column-averaged concentrations of GHGs

Total Carbon Column Observing Network (TCCON) is a ground-based observation network for column-averaged concentrations of GHGs (averaged concentrations from the surface of the earth to the top of the atmosphere), and provides an essential validation resource for the satellitebased GHG observation as well as modeling.

> Rikubetsu TCCON site at Rikubetsu Integrated Stratospheric Observation Center, NIES, Rikubetsu, Asyoro, Hokkaido (upper right) Solar tracker installed on the roof of the building (lower right) High-resolution FTS (IFS 120/5 HR)



### Ship-based Monitoring

JMA has conducted oceanographic observations in the western North Pacific by the Research Vessels (R/Vs) Ryofu Maru and Keifu Maru to monitor the long-term variability of ocean-related changes. Recently, JMA reconstructs surface ocean carbonate system parameters including monthly sea surface pH and oceanic  $CO_2$  sink after 1990 based on global observation databases, SOCAT (https://www.socat.info/) and GLODAP, and the gridded datasets are released through the JMAs website.





Observations of atmospheric and surface seawater  $pCO_2$  by two research vessels from 1980s to the present

R/V Ryofu Maru

R/V Keifu Maru

NIES has implemented GHG and ocean surface  $CO_2$  monitoring in the Pacific using volunteer observing ships since 1995. The observed data are published through the international database, SOCAT, and contribute to the evaluation of air-sea  $CO_2$  exchange and to the examination of ocean acidification.

Parallelly, NIES also has carried out observations for atmospheric GHGs and related species on the Japan-south eastern Asia route, in order to understand the temporal

variations of atmospheric tracer gases and their emissions from Asian countries.





Trans Future 5

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) operates the Research Vessel (R/V) Mirai, which is one of the largest research vessels in the world. With her high navigating capability, she has conducted physical, biogeochemical and geological observations associated with environmental changes in the world's oceans. Observation of atmospheric and

surface seawater partial pressures of  $CO_2$  (p $CO_2$ ) is one of the missions of the R/V Mirai. Recently, spatial and temporal variations of air-sea fluxes of  $CO_2$  in the Arctic Ocean, where impacts of global warming are predicted to be most clearly revealed, were clarified by historical data including measurements by the R/V Mirai.



R/V Mirai



Underway system for atmospheric and surface seawater pCO<sub>2</sub>, mounted on the R/V Mirai



Observations of atmospheric and surface seawater  $pCO_2$  by the R/V Mirai from 1998 to the present



Map for air-sea fluxes of CO<sub>2</sub> in the Arctic Ocean, which was constructed using historical data including measurements by the R/V Mirai

### Airborne-based Monitoring

JMA has observed GHGs in the upper air levels at an altitude of about 6 km, using aircraft with support from Japan Ministry of Defense since February 2011 during a regular flight between Atsugi and Minamitorishima once a month to clarify the three-dimensional distributions of greenhouse and other related gases.







Allelance 1501

The CONTRAIL (Comprehensive Observation Network for Trace Gases by Airliner) project is conducted by NIES, Meteorological Research Institute, Japan Airlines (JAL), JAMCO and JAL Foundation. The project observes  $CO_2$  and other greenhouse gases by Continuous  $CO_2$  Measuring Equipment and Automatic air Sampling Equipment onboard Boeing 777 aircraft operated by JAL. By using commercial airliners flying regularly, the frequency and geographical coverage of observations have been significantly improved.

(CONTRAIL http://www.cger.nies.go.jp/contrail/)



**Observation routes** 



Boeing 777 aircraft and two research equipment

### Satellite-based Monitoring



GOSAT



GOSAT-2



Whole-atmosphere monthly mean CO<sub>2</sub> concentration and its trend based on GOSAT observations from April 2009 to July 2018 (http://www.gosat.nies.go.jp/en/recent-global-co2.html)



Whole-atmosphere monthly mean CH<sub>4</sub> concentration and its trend based on GOSAT observations from April 2009 to July 2018 (http://www.gosat.nies.go.jp/en/recent-global-ch4.html)

The Greenhouse Gases Observing Satellite (GOSAT), launched in 2009, is the world's first satellite dedicated to measuring the atmospheric concentrations of  $CO_2$  and  $CH_4$ , two major GHGs, from space.

The purpose of GOSAT is to estimate emissions and absorptions of  $CO_2$ and  $CH_4$  on a sub-continental scale (several thousand square kilometers) more accurately, and to assist environmental administration in evaluating the carbon balance of the land ecosystem and making assessments of regional emissions and absorptions.

GOSAT observes the sunlight, that passes through the Earth's atmosphere, reflects off the Earth's surface, and reaches to the satellite, with a very high spectral resolution. By analyzing the observed spectra, the concentrations of gases in the Earth's atmosphere, such as  $CO_2$  and  $CH_4$ , can be estimated.

As the successor to the GOSAT mission, GOSAT-2 will be launched in October 2018 to continue global GHGs measurements started by GOSAT nine years ago, with its further advanced earth observation instruments. GOSAT and GOSAT-2 data are and will be publicly available after periodical validations using more accurate ground-based data. These validated data

are being utilized in the study to understand the relationship between climate change and carbon cycle.

The Paris Agreement requires its parties to submit their annual greenhouse gas emission inventory data to the United Nations. Validated GOSAT-2 data will also help evaluate and improve GHG inventories of both developed and developing countries in an open and transparent way.

GOSAT, GOSAT-2, and related activities are jointly promoted by the Japanese Ministry of the Environment (MOE), the National Institute for Environmental Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA) in collaboration with international partners.



Simulated global distribution of surface CO<sub>2</sub> concentrations on April 1st, 2015 based on GOSAT data

(https://data2.gosat.nies.go.jp/gallery/L4B/concmov/concmov.html)

### **Upscaling Terrestrial Carbon and GHG Fluxes**

#### Monitoring of forest carbon dynamics

Long-term monitoring of forest dynamics can help us estimate changes in forest carbon stocks more accurately. The monitoring plot network operated by Forestry and Forest Products Research Institute (FFPRI) covers the forests from Siberia to the Equator and supplies vital insights into the mechanisms underlying the current responses of ecosystems to the climate and the possible future of East and Southeast Asia under global change scenarios.



Ground-based inventory for carbon stock estimation





Monitoring plots in the network Copyright© T-worldatlas All rights Reserved.

Annual fluctuations in carbon stocks at the monitoring plots

## Monitoring of GHG flux in terrestrial ecosystems using Eddy Covariance flux towers and their network



Fuji-Hokuroku, Japan (NIES)



Takayama, Japan (AIST)



Automated chambers for soil efflux monitoring at Pasoh, Malaysia (NIES)



Teshio, Japan (Hokkaido Univ., NIES)



Sakaerat, Thailand (AIST)



Mae Klong, Thailand (AIST)

Poker Flat Research Range Flux Observation Supersite in Alaska, USA (JAMSTEC, IARC)

Location of AsiaFlux-registered

flux monitoring sites (http://asiaflux.net)

Monitoring of GHGs such as  $CO_2$  and  $CH_4$  in terrestrial ecosystem has been started in 1993 by the National Institute of Advanced Industrial Science and Technology (AIST), NIES, FFPRI, National Agriculture and Food Research Organization (NARO), JAMSTEC and other research institutes and universities in Japan using micrometeorological methods such as the eddy covariance method. Monitoring of soil efflux has also been conducted using automated chambers. NIES has been conducting soil warming experiments at 10 forest sites to evaluate the ecosystem response to climate change. "AsiaFlux" is a regional research network under FLUXNET, and NIES supports the secretariat office.



Forest, Plantation Fruit farm Paddy, Meadow, Crops Grassland, Wetland, Shrub, Steppe, Tundra, Desert Urban



### **Data Distribution Service**

#### World Data Center for Atmospheric GHG Concentrations

WDCGG is one of the World Data Centres under WMO's Global Atmosphere Watch (GAW) programme. It serves to gather, archive and provide data on GHGs (CO<sub>2</sub>, CH<sub>4</sub>, CFCs, N<sub>2</sub>O, etc.) and related gases (e.g., CO) in the atmosphere and ocean, as observed under GAW and other programmes. The website, operated since October 1990 by JMA, provides information on GHGs, including WDCGG publications and measurement data contributed by organizations and individual researchers around the world.



## Database for surface ocean CO $_2$ (SOCAT) and terrestrial GHG flux monitoring network (FLUXNET)

The International Integrated Ocean Surface  $CO_2$ Observation Database (Surface Ocean  $CO_2$  Atlas; SOCAT) project collects data on the partial pressure of  $CO_2$  in surface seawater from observational institutions around the world and promotes quality control and standardization for the database.



Observation routes based on SOCAT (https://www.socat.info/)

In terrestrial systems, the global-scale observation network FLUXNET promotes collecting site information, standardizing observation methods, developing data quality control procedures, and establishing and updating a database. AsiaFlux promotes networking Asian observation sites and collaborative research projects.



AsiaFlux Webpage (http://asiaflux.net)

## Data Integration and Inverse Model Estimation for GHG Sources and Sinks

To develop integrated observation and analysis systems, atmospheric transport models and inverse systems are being developed and improved for estimating regional to global-scale GHG fluxes. Intermittent large-scale emission such as from a forest (peat) fire or from an agricultural field is one of the essential targets.



Atmospheric CO<sub>2</sub> concentration fields simulated by an atmospheric transport model "NICAM-TM"



Surface  $CO_2$  fluxes estimated by a trial experiment with a new atmospheric GHG inverse system named NICAM-TM 4D-Var. The figures show monthly mean  $CO_2$  flux distributions, focusing on regional anomalies due to biomass burnings for southeast Asia in March (Left), South America in September (Mid), and Africa in September (Right), which are generated from pseudo observations.

(Niwa et al., 2017)

## **Demonstration of GHG Mitigation Options**

"Alternate Wetting and Drying (AWD)" is one of water management techniques to mitigate  $CH_4$  efflux from paddy fields. The paddy soil is dried and flooded alternately, and the paddy soil is oxidized to prevent anaerobic methane production from soil microorganisms. Despite less consumption of irrigation water compared to continuous flooding irrigation, yields were increased by AWD at most of the test sites in the Mekong Delta, Vietnam.

Japan International Research Center for Agricultural Sciences (JIRCAS) continues monitoring of the GHG emissions from the paddy since 2013. The accumulated data is expected to clarify the effects of the AWD technology on GHG emissions and rice yields as compared with conventional irrigation methods.



Weekly air sampling to monitor GHG emissions from paddy fields in the Mekong Delta, Vietnam

## **Providing Additional Information to Complement National Inventories**

The reliability of evaluations of natural and anthropogenic sources and sinks is improved by combining data with such advanced analysis systems as "top-down" and "flux upscaling" methods.



Estimating national GHG emissions

## **Collaboration Among** Japanese Agencies and **Institutions to Support** Stakeholders in Solving Social Issues

Relevant Japanese institutions and agencies for GHG observation and analysis will cooperate to improve up-to-date analysis systems and data coverage in Asia–Oceania for better estimation of emission distributions with sufficient accuracy, and to provide the data and knowledge to stakeholders in time with the Global Stocktake Process under the Paris Agreement for verification of impacts of mitigation actions.

#### Japanese Alliance for Climate Change Observation (JACCO)





#### Member of Steering Committee of JACCO

Cabinet Office / Ministry of Internal Affairs and Communications (MIC) / Ministry of Education, Culture, Sports, Science and Technology (MEXT) / Ministry of Agriculture, Forestry and Fisheries (MAFF) / Forestry Agency / Fisheries Agency (FA) / Ministry of Economy, Trade and Industry (METI) / Ministry of Land, Infrastructure, Transport and Tourism (MLIT) / Geospatial Information Authority of Japan (GSI) / Japan Meteorological Agency (JMA) / Japan Coast Guard / Ministry of the Environment (MOE)

National Institute of Information and Communications Technology (NICT) / National Institute of Polar Research (NIPR) / Japan Aerospace Exploration Agency (JAXA) / Japan Agency for Marine-Earth Science and Technology (JAMSTEC) / National Agriculture and Food Research Organization (NARO) / Japan International Research Center for Agricultural Sciences (JIRCAS) / Forestry and Forest Products Research Institute (FFPRI) / Japan Fisheries Research and Education Agency (FRA) / National Institute of Advanced Industrial Science and Technology (AIST) / National Institute for Environmental Studies (NIES)

#### A-PLAT (CLIMATE CHANGE ADAPTATION INFORMATION PLATFORM)

A-PLAT is a portal that provides centralized information related to the impacts of climate change. Aiming to support the local governments, businesses, and individuals to consider adaptation measures to climate change, it collects and arranges scientific knowledge (observation data, climate predictions, and impact predictions), and promotes information sharing among stakeholders.



#### Data Catalog for GHG Observation and Related Products

AsiaFlux	http://asiaflux.net
Climate Change Adaptation Platform (A-PLAT)	http://www.adaptation-platform.nies.go.jp/en/index.html
Comprehensive Observation Network for TRace gases by	AIrLiner (CONTRAIL) http://www.cger.nies.go.jp/contrail/
Data Integration & Analysis System (DIAS)	http://www.diasjp.net/en/
Data Portal for FLUXNET (Fluxdata)	http://fluxnet.fluxdata.org/
Forestry and Forest Products Research Institute (FFPRI)	Database https://www.ffpri.affrc.go.jp/en/database.html
GHG Emissions Data of Japan	http://www-gio.nies.go.jp/aboutghg/nir/nir-e.html
Global Earth Observation System of Systems (GEOSS) I	Portal http://www.geoportal.org/
GLobal Ocean Data Analysis Project (GLODAP) https://climatedataguide.ucar.edu/climate-data/glodap-global-ocean-data-analysis-project-carbon	
Greenhouse gases Observing SATellite (GOSAT) Data A	rchive Services https://data2.gosat.nies.go.jp/index_en.html
Japan Aerospace Exploration Agency (JAXA) Observation / Research Result Database http://global.jaxa.jp/projects/db/index.html	
Japan Agency for Marine-Earth Science and Technology (JAMSTEC) Databases http://www.jamstec.go.jp/e/database/	
Japan International Research Center for Agricultural Sciences (JIRCAS) Database https://www.jircas.go.jp/en/database	
Japan Meteorological Agency (JMA) Observation Data/Oceanic Carbon Cycle Products https://www.data.jma.go.jp/gmd/kaiyou/db/vessel_obs/data-report/html/ship/ship_e.php https://www.data.jma.go.jp/gmd/kaiyou/english/oceanic_carbon_cycle_index.html	
National Institute for Environmental Studies (NIES) Global Environmental Database http://db.cger.nies.go.jp/portal/	
National Institute of Polar Research (NiPR) Database	http://www.nipr.ac.jp/english/database/
Office for Coordination of Climate Change Observation	(OCCCO) http://occco.nies.go.jp/e_index.html
Surface Ocean CO <sub>2</sub> Atlas (SOCAT)	https://www.socat.info/
Total Carbon Column Observing Network (TCCON)	http://www.tccon.caltech.edu/
World Data Centre for Greenhouse Gases (WDCGG)	https://gaw.kishou.go.jp/

Pictures and figures by curtesy of: Ministry of Agriculture, Forestry and Fisheries (MAFF); Forestry Agency; Japan Meteorological Agency (JMA); Japan Aerospace Exploration Agency (JAXA); Japan Agency for Marine-Earth Science and Technology (JAMSTEC); Japan International Research Center for Agricultural Sciences (JIRCAS); Forestry and Forest Products Research Institute (FFPRI); National Institute of Advanced Industrial Science and Technology (AIST); National Institute for Environmental Studies (NIES)

#### Task Team on the International Initiatives towards Promotion of Greenhouse Gas Observation

Office for Coordination of Climate Change Observation National Institute for Environmental Studies (NIES) 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan Telephone : +81-29-850-2980 Fax : +81-29-858-2645 E-mail : occco@nies.go.jp http://occco.nies.go.jp/e\_index.html

