Monitoring of GHG sinks & sources to contribute to the Global Stocktake: Challenges in Asia and Oceania

Nobuko Saigusa, Akihiko Ito, Yosuke Niwa, Toshinobu Machida, Tsuneo Matsunaga, Hiroshi Tanimoto

Earth System Division,
National Institute for Environmental Studies (NIES), Japan

Recent Activities

- Outcome of Japan Pavilion Seminar at COP26
- Current status and issues of estimation of GHG sinks & sources in global, Asia-Oceania, and point scales

Outcome of Japan Pavilion Seminar at COP26

1) **Monitoring of GHG sinks & sources to contribute to climate change mitigation**
2) **Asia-Pacific Climate Change Adaptation Information Platform (AP-PLAT)**

Supported by Ministry of the Environment Japan, NIES, JAXA, IGES

2nd November 2021

Mitigation

1)

The Greenhouse Gas (GHG) Monitoring Project for the Global Stocktake 2023

— The COP26 Japan Pavilion Seminar, 2nd November 2021, 15:00-16:30 (UTC+0) at the Japan Pavilion

Presentation files are available at: https://esd.nies.go.jp/cop26/

Adaptation

2)

Development and utilization of information platforms towards climate resilient societies in Asia-Pacific Region

— The COP26 Japan Pavilion Seminar, 2nd November 2021, 10:30-12:00 (GMT) at Japan Pavilion

Outcome of Japan Pavilion Seminar at COP26

The Greenhouse Gas (GHG) Monitoring Project for the Global Stocktake 2023

— The COP26 Japan Pavilion Seminar, 2nd November 2021, 15:00-16:30 (UTC+0) at the Japan Pavilion

Moderator: Tomohiro Oda, USRA, USA

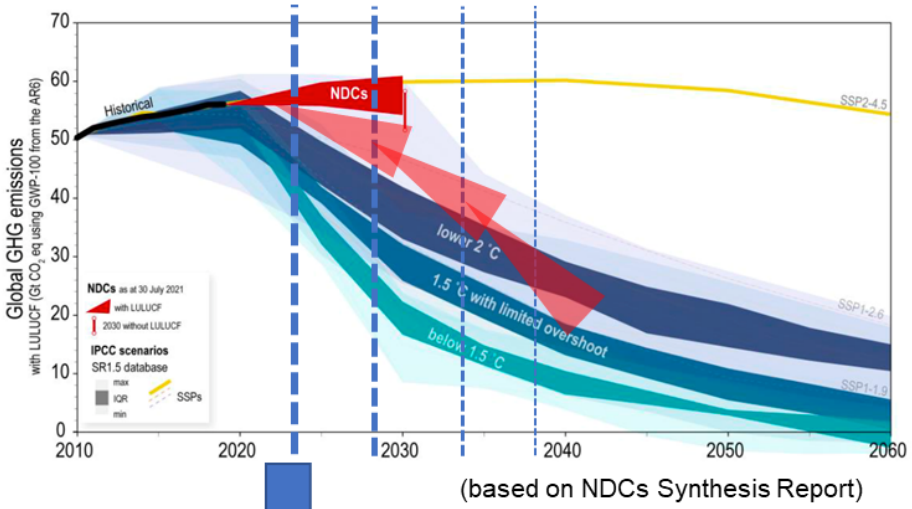
1. GHG monitoring project of Japan for the Global Stocktake 2023
   Akihiko Ito, NIES, Japan
2. Decade-long global GHG observation by GOSAT towards the Global Stocktake
   Hiroshi Suto, JAXA, Japan
3. Satellite data helping estimation and evaluation of regional CO_2 and CH_4 fluxes
   Prabir Patra, JAMSTEC, Japan
4. Pilot national-scale estimates of carbon dioxide and methane emissions and removals from space-based measurements
   David Crisp, JPL/Caltech, USA
5. The UNFCCC BUR preparation in Mongolia using GOSAT satellite data and its application to other countries
   Masataka Watanabe, Chuo University, Japan
6. Panel discussion

https://esd.nies.go.jp/cop26/seminar-2-11-2021.html

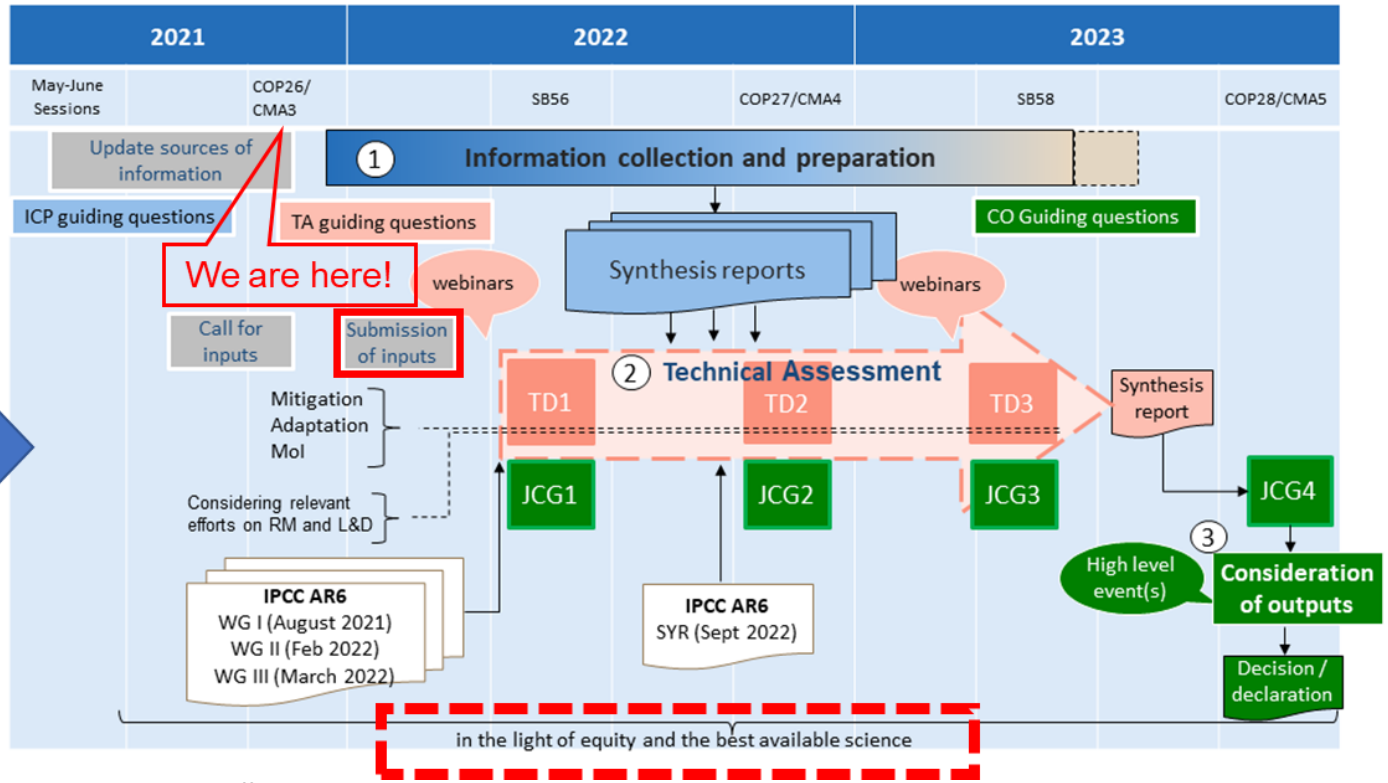
Outcome of Japan Pavilion Seminar at COP26

Proposed schedule of Global Stocktake 2023 [after UNFCCC web site]

How can we achieve 'the best available science'?



(based on NDCs Synthesis Report)



Ito (2021) "GHG monitoring project of Japan for the Global Stocktake 2023"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

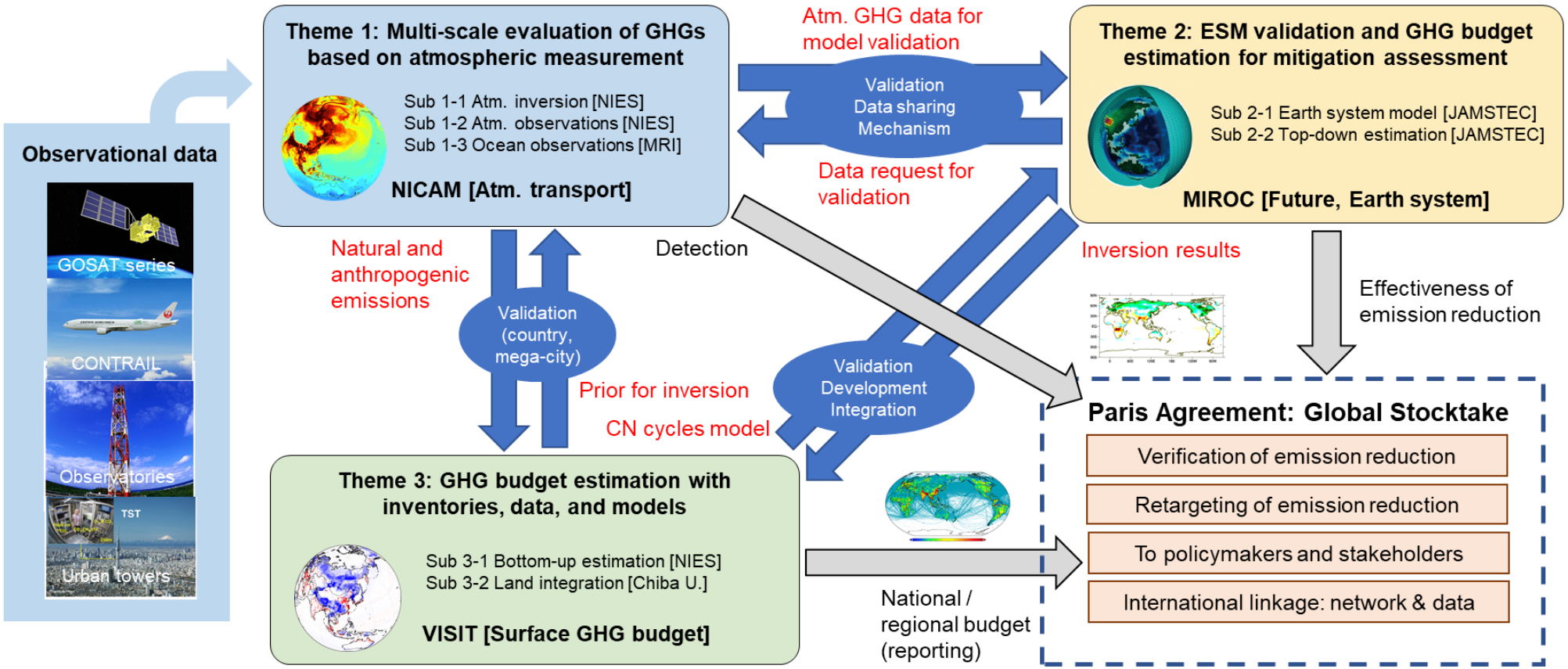
Outcome of Japan Pavilion Seminar at COP26

GHG monitoring project for Global Stocktake by Japan Research Activities

SII-8: Comprehensive Study on Multi-scale Monitoring and Modeling of Greenhouse Gas Budgets

Term: from April 2021 to March 2024 Funding: Ministry of the Environment, Japan

Main purpose: Multi-scale [urban ~ global] GHG budget estimation for the Global Stocktake



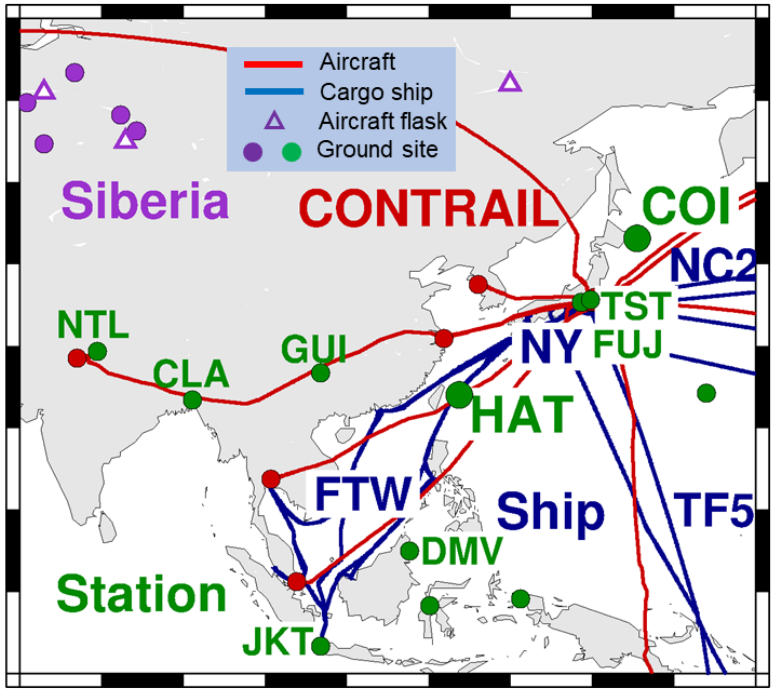
Ito (2021) "GHG monitoring project of Japan for the Global Stocktake 2023"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

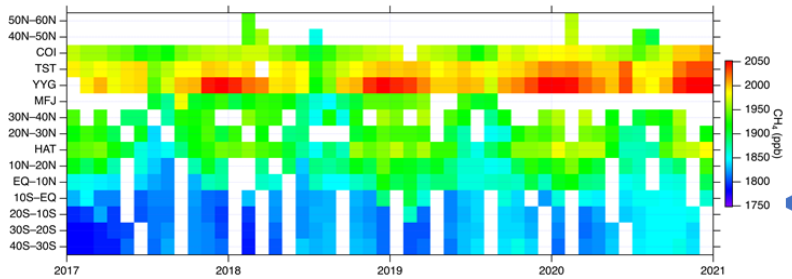
Outcome of Japan Pavilion Seminar at COP26

GHG observation by ground observatory and aircraft

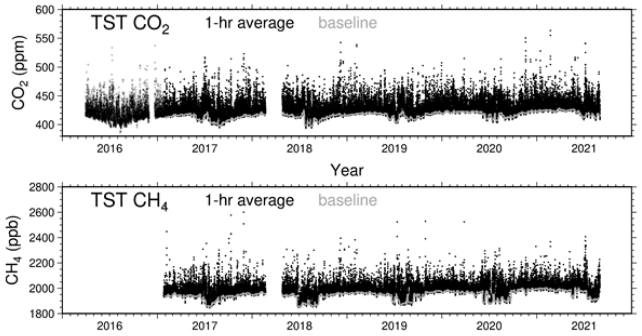
(Courtesy of Y. Tohjima, Y. Terao, T. Umezawa, T. Machida, S. Nakaoka)

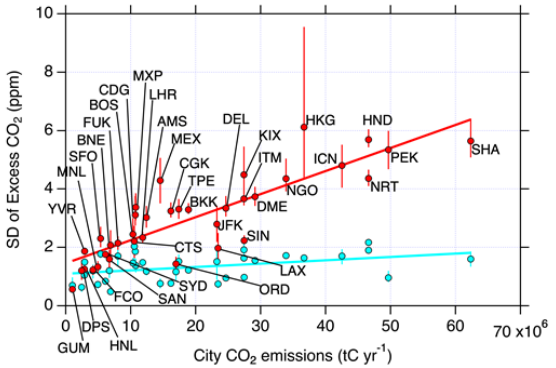
NIES observation network



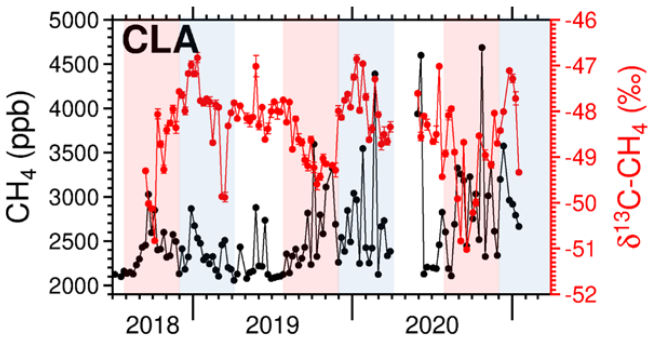


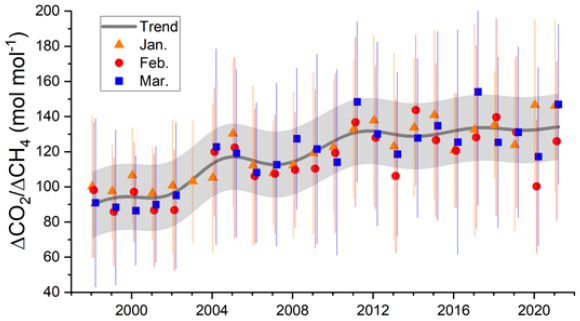
■ Development of urban GHG observation system



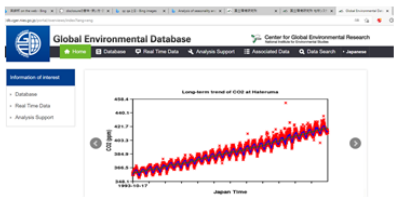


■ Source and emission estimation based on isotope and multi species observations





■ Near-real-time database for multi-scale atmospheric GHG observations

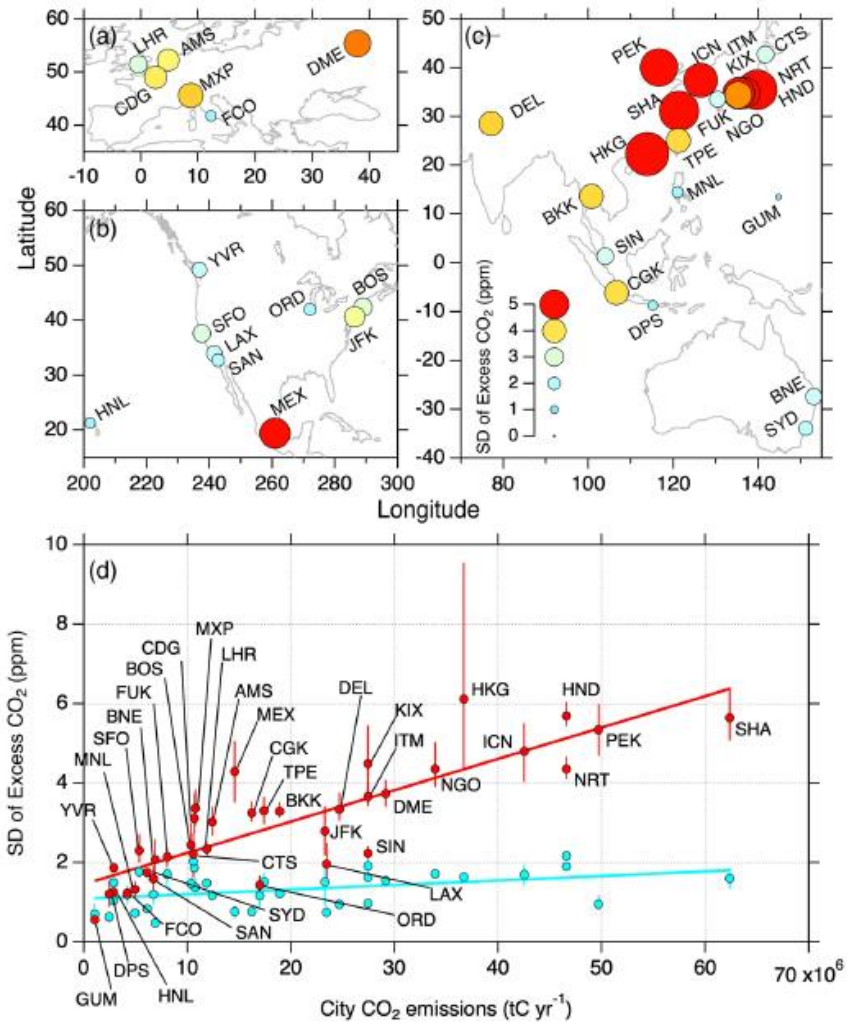


Ito (2021) "GHG monitoring project of Japan for the Global Stocktake 2023"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

Statistical characterization of urban CO_2 emission signals observed by commercial airliner measurements (Umezawa *et al*., 2020, Sci. Rep.)

Comprehensive Observation Network for Trace gases by Airliners (CONTRAIL) Program

- Using vertical atmospheric CO_2 data obtained onboard commercial aircraft to 36 airports worldwide
- Based on flight-to-flight variations of CO_2 enhancements downwind of neighboring cities
- Particularly CO_2 variability near the ground (~1km altitude) at an airport



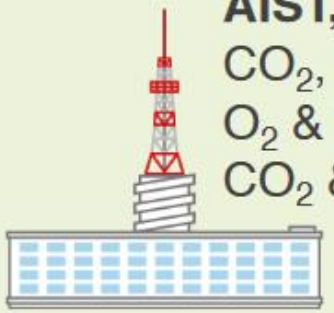
Variability of CO_2 enhancements
(a–c) Maps of the SD values at 1.0–1.5 km altitudes.
(d) Relationship of the SD at 1.0–1.5 km (red) and 4.0–4.5 km (light blue) altitude bins with city CO2 emissions based on the ODIAC dataset 26,27. Airport codes are indicated for the data from 1.0–1.5 km.

Paper: https://www.nature.com/articles/s41598-020-64769-9.pdf
Press release (in Japanese) https://www.nies.go.jp/whatsnew/20200515-2/20200515-2.html

Atmospheric observations of CO_2, $^{14}CO_2$ and O_2 concentrations to capture fossil fuel CO_2 emissions from the Greater Tokyo Area (Terao et al., 2020)

CO_2 from natural gas
$^{14}CO_2$ = zero, OR* = 1.97

Yoyogi site (52m)
AIST, NDA, NIES
CO_2, CH_4, CO, …
O_2 & $^{14}CO_2$
CO_2 & heat flux



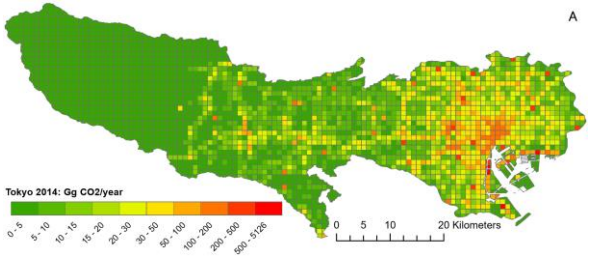
NIES Tokyo Skytree observatory (250m)
CO_2, CH_4, CO, …
O_2 & $^{14}CO_2$

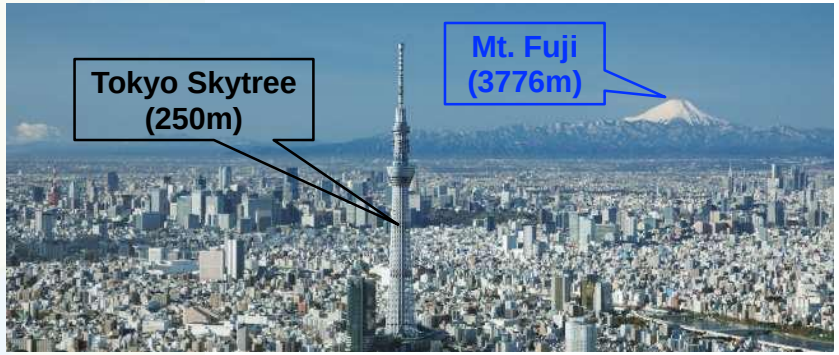
CO_2 from gasoline
$^{14}CO_2$ = zero, OR = 1.5

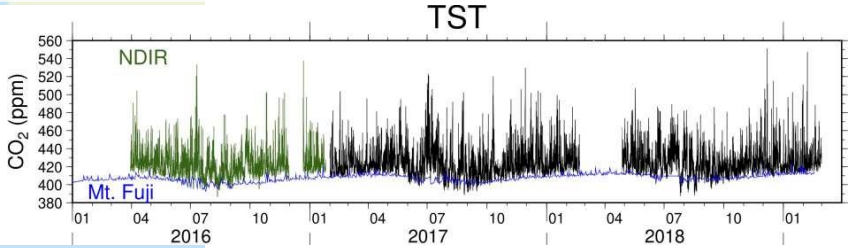
Biospheric CO_2
$^{14}CO_2$ included, OR = 1.1 (plants) & 1.25 (human)

*Oxidative Ratio; -O_2/CO_2 (mol/mol)

Anthropogenic CO_2 emission from Tokyo (bottom-up inventory)







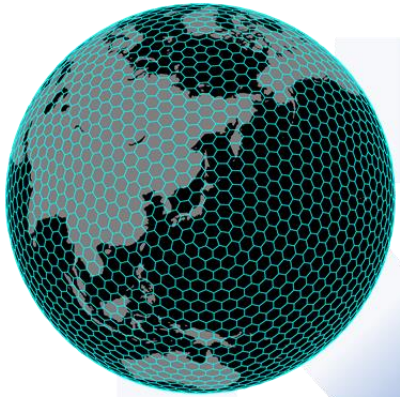
https://presentations.copernicus.org/EGU2020/EGU2020-12366_presentation.pdf

Outcome of Japan Pavilion Seminar at COP26

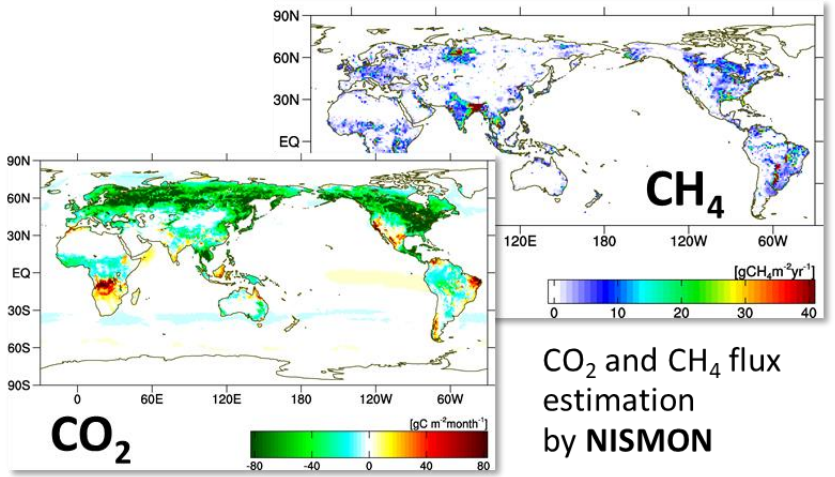
GHG budget estimation by a numerical model

(Courtesy of Y. Niwa)

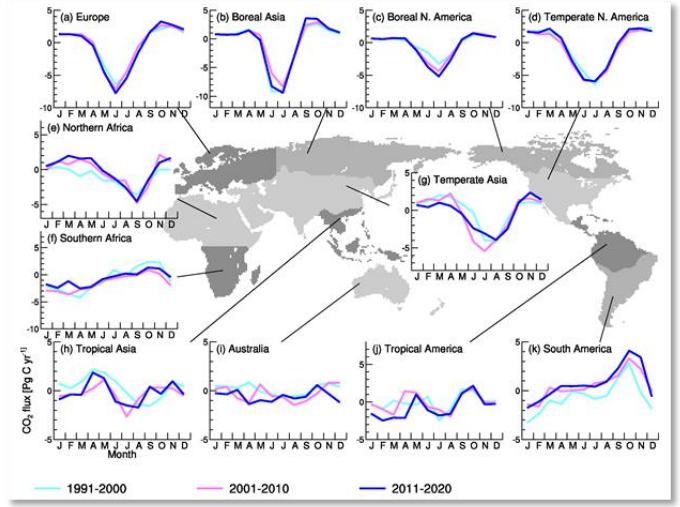
Atmospheric model NICAM-TM



■ Global long-term analyses of GHG budgets

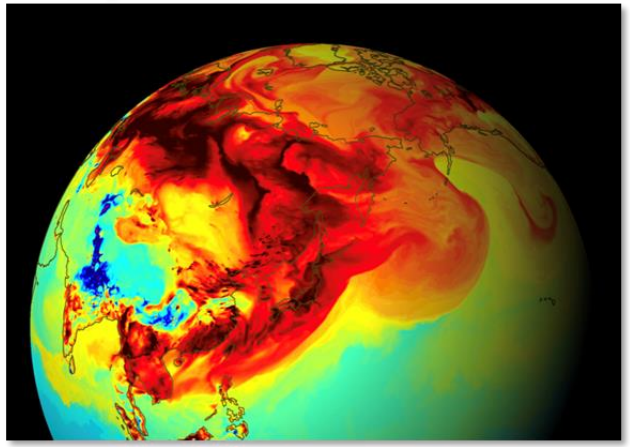


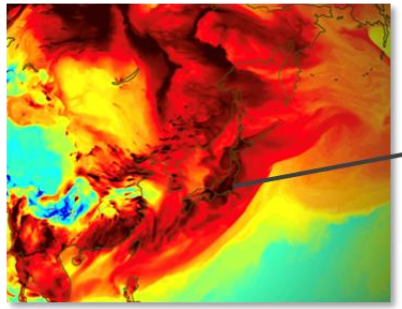
CO_2 and CH_4 flux estimation by **NISMON**



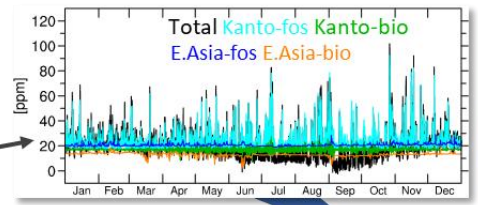
Regional seasonal cycles of natural CO_2 fluxes for 1991-2000

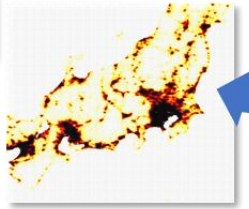
■ High-resolution simulations of GHGs





Global high-resolution simulation of CO_2 (~14km)





Estimation of emissions from Japan/megacity

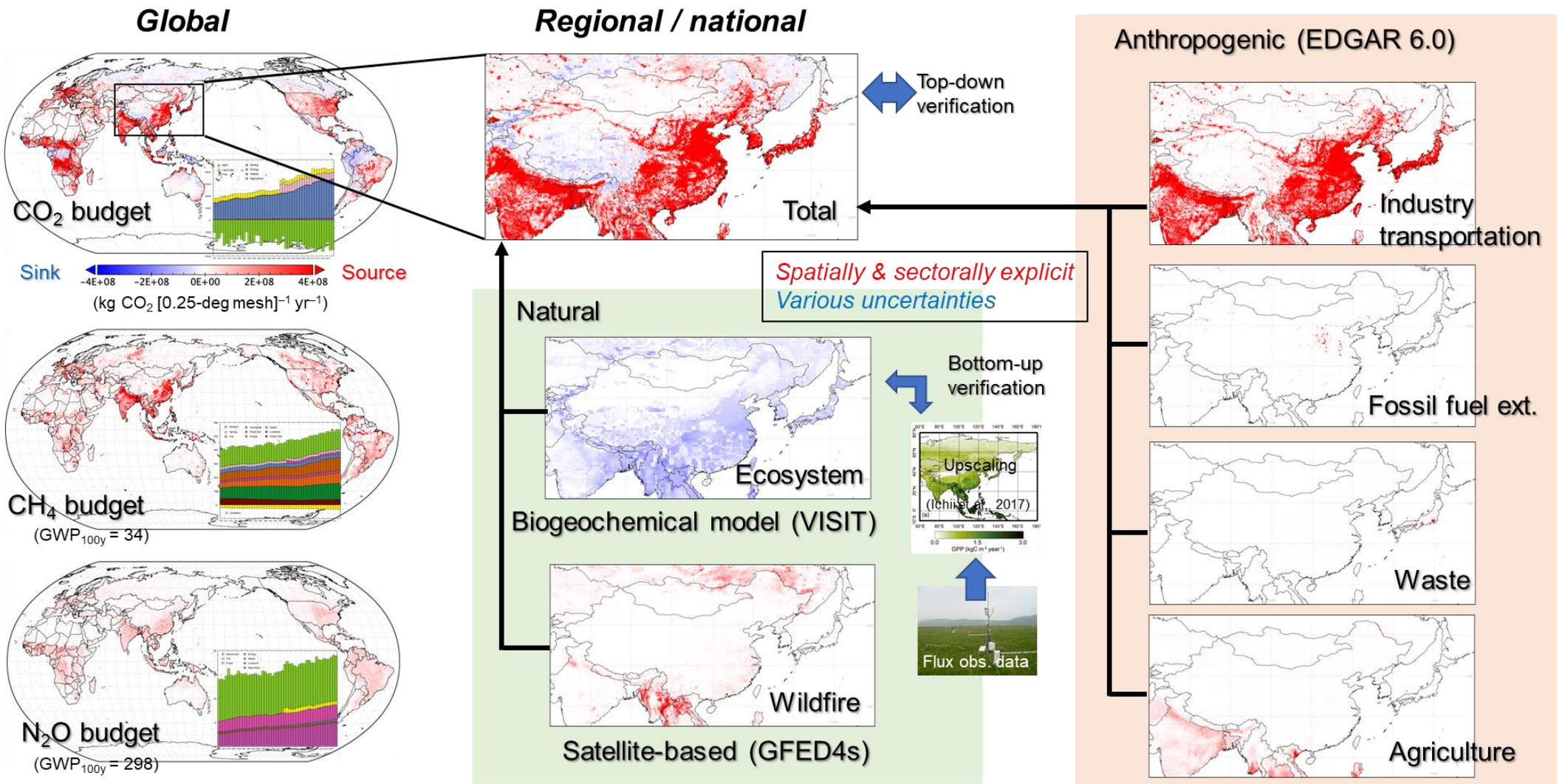
Tokyo Skytree (250m): CO_2, CH_4, CO, O_2, $^{14}CO_2$, …

■ Support to make a strategy for efficient observation networks

Ito (2021) "GHG monitoring project of Japan for the Global Stocktake 2023" https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

Outcome of Japan Pavilion Seminar at COP26

Bottom-up estimation of regional and national GHG budgets [2000-2018]



Ito (2021) "GHG monitoring project of Japan for the Global Stocktake 2023"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

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Changes in Methane (CH_4) emissions and concentrations

A joint work with inventory emission group and satellite observations

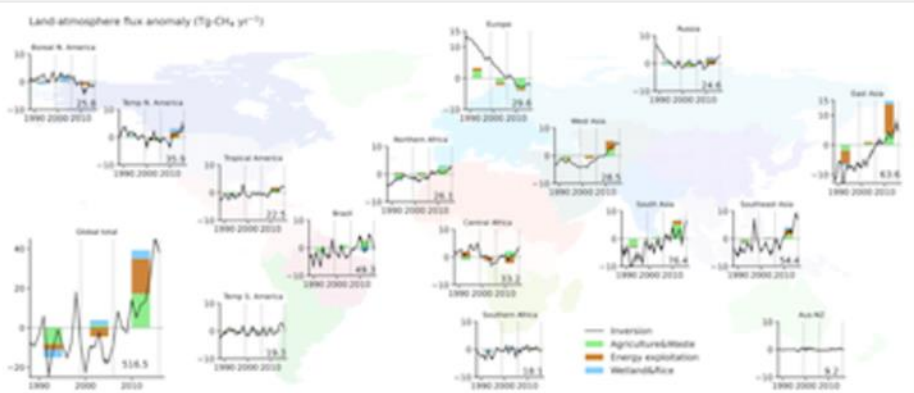


Figure 1. Timeseries (1988-2016) of global and regional CH_4 emission anomalies for 2 inversion ensembles, and the emission changes from 3 aggregated sectors during the three growth rate phases (bar plots). A long-term (2000-2016) mean for each region, given at the bottom-right of each panel (in Tg yr^{-1}), is subtracted to calculate the emission anomalies. The average emissions and range (shaded) for the two inversion cases are shown.

Volume 99 (2021) Issue 2 Pages 309-337

Emissions from the Oil and Gas Sectors, Coal Mining and Ruminant Farming Drive Methane Growth over the Past Three Decades

Naveen CHANDRA, Prabir K. PATRA, Jagat S. H. BISHT, Akihiko ITO, Taku UMEZAWA, Nobuko SAIGUSA, Shinji MORIMOTO, Shuji AOKI, Greet JANSSENS-MAENHOUT, Ryo FUJITA, Masayuki TAKIGAWA, Shingo WATANABE, Naoko SAITOH, Josep G. CANADELL

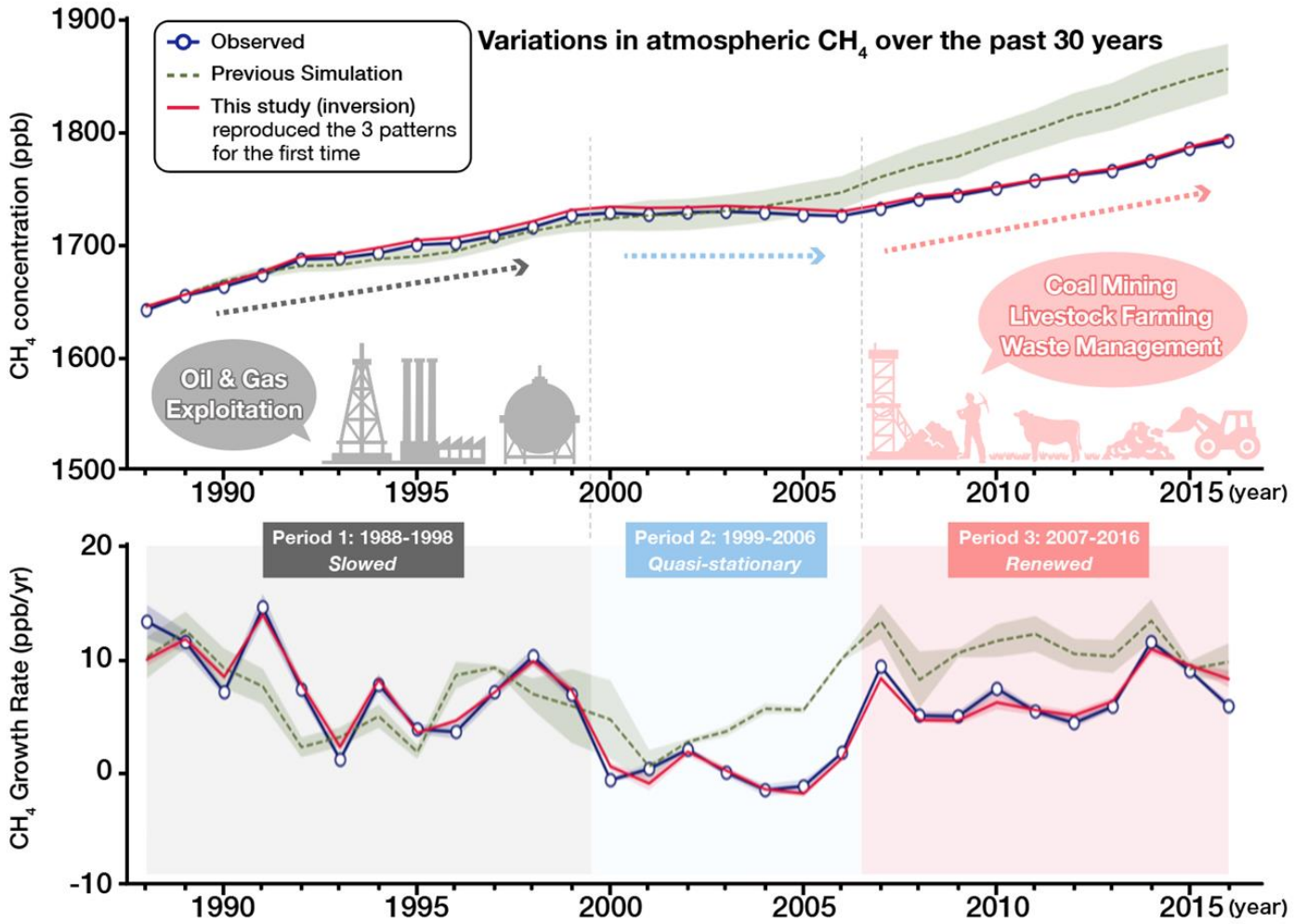
Methane (CH_4) is an important greenhouse gas and plays a significant role in tropospheric and stratospheric chemistry. Despite the relevance of methane (CH_4) in human-induced climate change and air pollution chemistry, there is no scientific consensus on the causes of changes in its growth rates and variability over the past three decades. We use a well-validated chemistry–transport

https://doi.org/10.2151/jmsj.2021-015

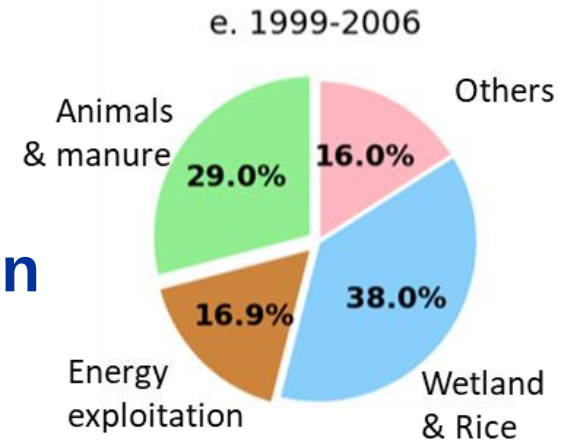
Patra (2021) "Satellite data helping estimation and evaluation of regional CO2 and CH4 fluxes"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

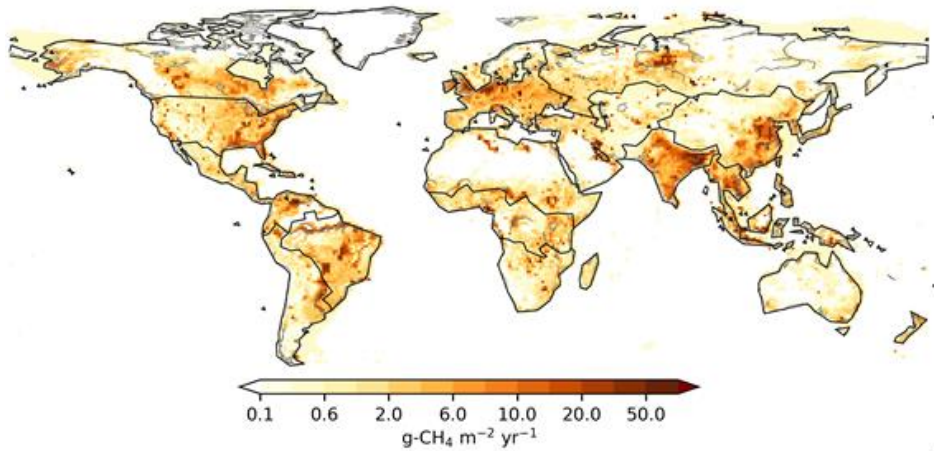
Outcome of Japan Pavilion Seminar at COP26

Methane concentrations and emissions over the past three decades:
Human activity in oil, gas and coal exploitation, livestock farming and waste management



CH_4 emission





Patra (2021) "Satellite data helping estimation and evaluation of regional CO2 and CH4 fluxes"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

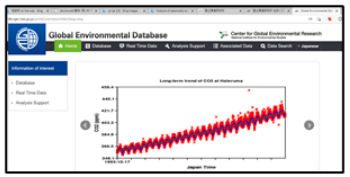
Chandra et al., JMSJ, 2021

Outcome of Japan Pavilion Seminar at COP26

Contributions of SII-8 project to Global Stocktake

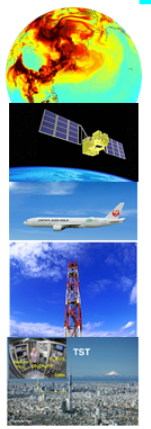
This project is planning to provide a summary report of global-, regional-, and country-level GHG budgets in support of the **Global Stocktake**, including contents shown below:

Database [open]



Gap & challenge
=> real-time:
within 1 year!

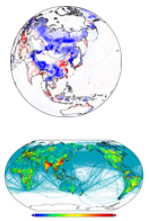
Top-down estimations



Global
- CO_2, CH_4 budget maps: 1 x 1deg, NICAM, 1990–2020
- CO_2, CH_4, N_2O budget map: region divisions, MIROC4-ACTM, 2000–2020
- CO_2, CH_4、N_2O decadal summary table

Country / region
- CO_2、CH_4 budget: regions, NICAM, 1990–2020
- CO_2、CH_4, N_2O budgets: 11–15 regions / top 20 emitters, 2000–2019
- Atmospheric CO_2, CH_4concentrations: ground, ship, aircraft, 1994–2021

Bottom-up estimations



Global
- Natural CO_2, CH_4, N_2O budget maps: 0.5 x 0.5deg, VISIT, 1990–2020
- Anthropogenic inventories: 0.25 x 0.25deg, 1990–2018
- CO_2, CH_4, N_2O decadal summary table

Country / region
- CO_2, CH_4, N_2O budget: regions (RECCAP2 regions), 1990–2018
- Land CO_2 budget (GPP, NEE): Asia、0.25 × 0.25deg, flux scale-up, 2000–2020

Ito (2021) "GHG monitoring project of Japan for the Global Stocktake 2023"
https://esd.nies.go.jp/cop26/pdf/presentation-slides/1_COP26_JPseminar_Ito_20211102_v5.pdf

Outcome of Japan Pavilion Seminar at COP26

JAPAN PAVILION

Japan Pavilion Seminar at COP26

Development and utilization of information platforms towards climate resilient societies in Asia-Pacific Region

Opening remarks (Video message)

Mr. Yutaka Shoda Vice-Minister for Global Environmental Affairs, MOEJ

Closing remarks

Dr. Masahide Kimoto President, NIES

SPEAKERS

Dr. Yuji Masutomi Section Head, CCCA, NIES

Dr. Tetsuo Kuyama Director, Bangkok Regional Center, IGES

Dr. Youichi Ishikawa Director, Center for Earth Information Science and Technology (CEIST), Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Ms. Yvette Kerslake Technical Advisor, Science to Services, Pacific Climate Change Centre

Dr. Kim van Nieuwaal Strategic advisor, Climate Adaptation Services

Dr. Linda Anne Stevenson Head of Knowledge Management and Scientific Affairs, Asia-Pacific Network for Global Change Research (APN)

Dr. Mozaharul Alam Regional Coordinator, Asia and the Pacific Office, United Nations Environment Programme (UNEP)

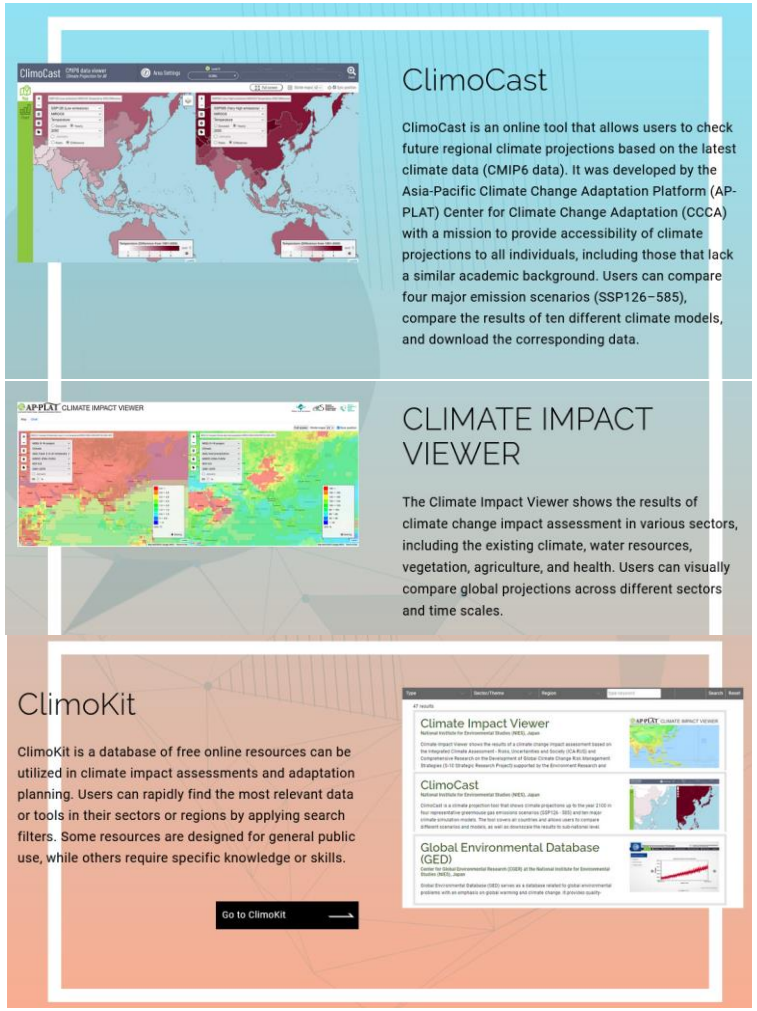
Contact information

Yuji Masutomi masutomi.yuji@nies.go.jp **Tetsuo Kuyama** kuyama@iges.or.jp **AP-PLAT website** https://ap-plat.nies.go.jp/

https://esd.nies.go.jp/cop26/pdf/COP26_JapanPavilionSeminar_AP-PLAT.pdf

https://ap-plat.nies.go.jp/

AP-PLAT
Asia-Pacific Climate Change Adaptation Information Platform



Outcome of Japan Pavilion Seminar at COP26

Summary

- The collective assessment of the Global Stocktake (GST) should be conducted based on the best available science, but the consensus does not seem to be clear yet.
- A three-year project to comply with the GST has been launched with the support of the Ministry of the Environment. [SII-8] “Comprehensive Study on Multi-scale Monitoring and Modeling of Greenhouse Gas Budgets”
- The SII-8 project focuses on the contribution to the first and following GSTs. In addition to publishing a summary (for policy maker) report, the outcomes would become available from appropriate open data repositories.
- Climate change adaptation measures are also important to contribute to the Paris Agreement, and NIES plans to disseminate adaptation information to the Asia-Pacific region through the online platform, "AP-PLAT".

Recent Activities

- Outcome of Japan Pavilion Seminar at COP26
- Current status and issues of estimation of GHG sinks & sources in global, Asia-Oceania, and point scales

Concept

Contribution to the global stocktake process

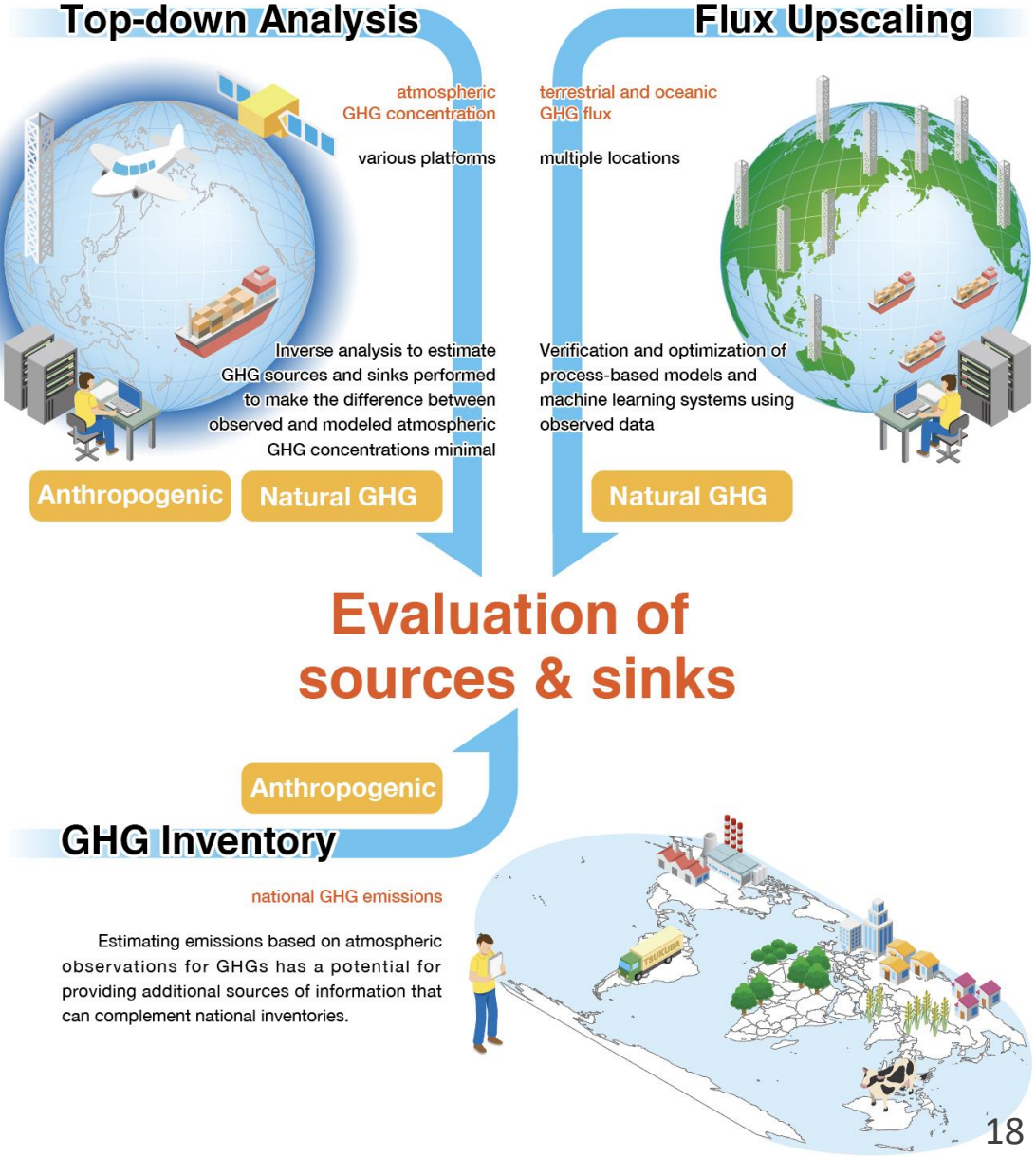
1. Top-down analysis
2. Flux upscaling
3. GHG Inventory
Improve their accuracy by identifying the cause of discrepancy

Provide global gridded GHG sink/source data to contribute to the Global Stocktake under the Paris Agreement and publish synthesis report by FY2022 (tentative)

Estimate long-term anthropogenic and natural GHG budgets with high spatio-temporal resolution

⇒Assess the **past** socio-economic scenarios used in the climate models

⇒Predict the effects of climate change mitigation measures in the near future

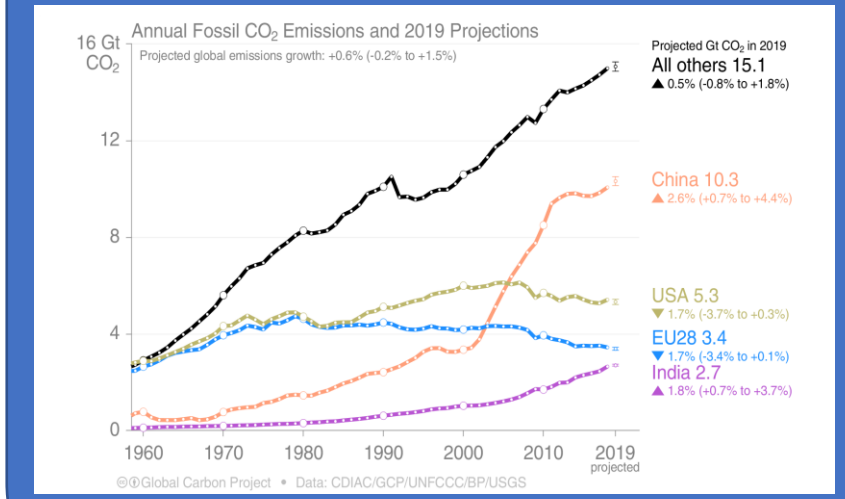


Concept

Potential of atmospheric observation based approaches for GHG-budget estimates

Reducing uncertainties in rapid increase in anthropogenic emissions from emerging & developing countries

Annual fossil CO_2 emissions

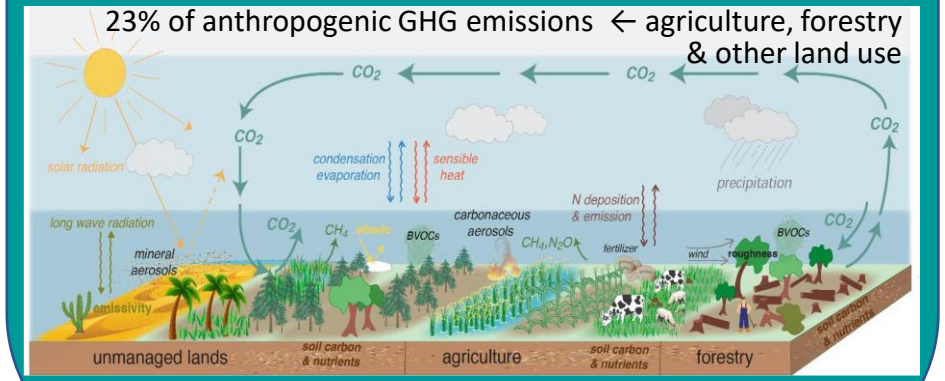


GCP Carbon Budget 2019
https://www.globalcarbonproject.org/carbonbudget/

Providing additional source of data for

- ✓ Intermittent GHG emissions from agricultural land, wetland, etc.;
- ✓ Large-scale forest and peatland fires induced by climatic anomalies;
- ✓ Anthropogenic GHG sinks (plantation, BECCS, CO_2 removal (CDR), etc.).

23% of anthropogenic GHG emissions ← agriculture, forestry & other land use



IPCC Special Report Climate Change and Land
https://www.ipcc.ch/srccl/

Near real-time monitoring for anthropogenic emissions of GHGs & SLCPs from megacities to enhance motivation of emission reduction measures

C40 Cities
https://www.c40.org/cities

Progress in top-down analysis

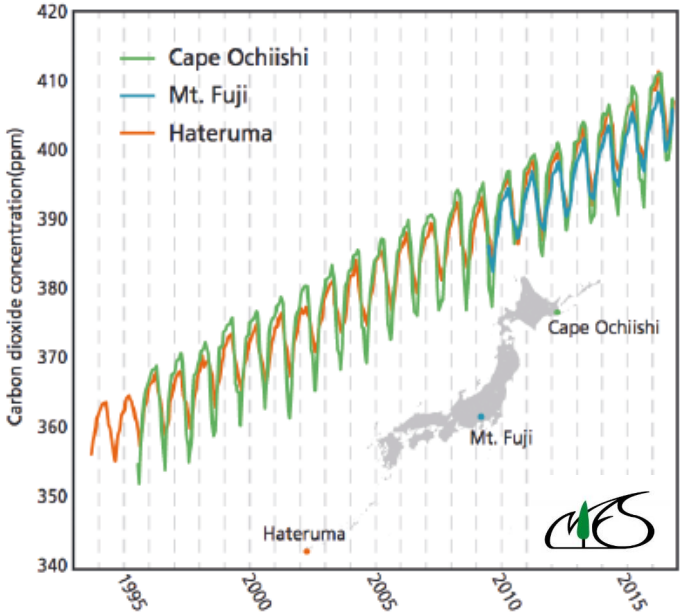
Ground-based Monitoring

Atmospheric concentrations of GHGs at near-ground levels

Monitoring station, Cape Ochiishi

Monitoring station, Hateruma

Mt. Fuji automated weather station



Annual variations in CO_2 concentration

Observation components:
(e.g. Hateruma station):
CO_2, CH_4, N_2O, CO, H_2, O_2/N_2, NOx, SOx, O_3, CFCs, Rn, aerosol, ^{14}C, halocarbon, SF6, POPs

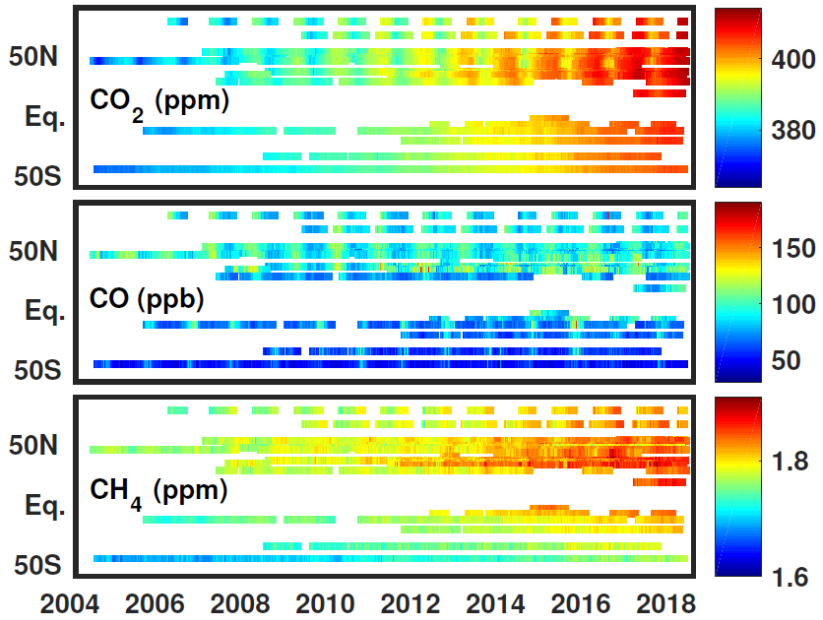
Data: WDCGG/GAW https://gaw.kishou.go.jp/
NIES Global Environmental Database
http://db.cger.nies.go.jp/portal/

World Data Centre for Greenhouse Gases

Column-averaged concentrations of GHGs

Total Carbon Column Observing Network (TCCON)
http://www.tccon.caltech.edu/

Rikubetsu **TCCON** site at Rikubetsu Integrated Stratospheric Observation Center, NIES, Rikubetsu, Asyoro, Hokkaido



Atmospheric CO_2, CO, and CH_4 concentrations observed by TCCON

Ship-based Monitoring

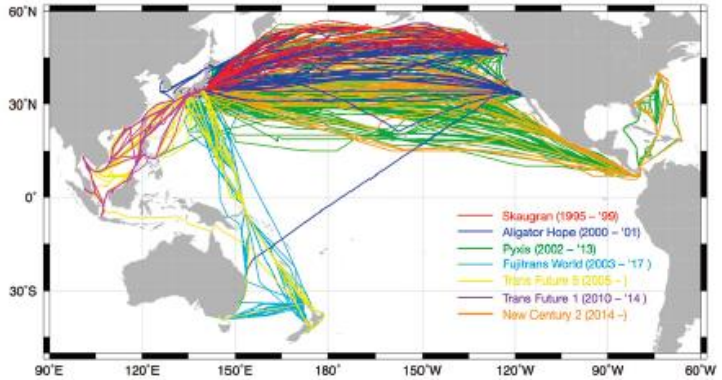
GHG and ocean surface CO_2 monitoring

Trans Future 5

New Century 2

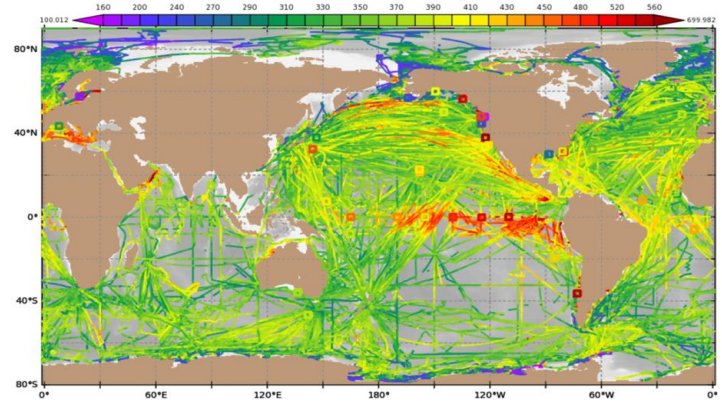
Fujitrans World

Monitoring in the western North Pacific by Volunteer Observing Ships (NIES)



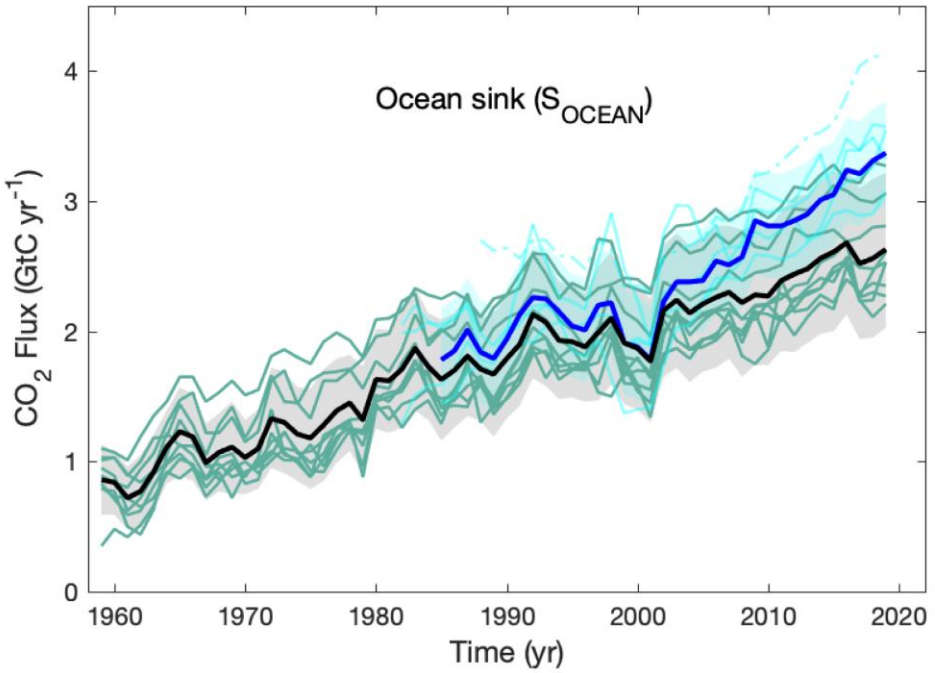
Observation routes

Contribution to global database



Data: SOCAT https://www.socat.info/

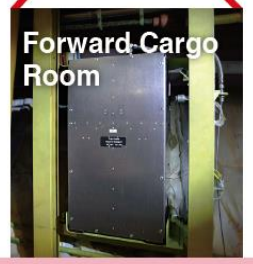
Global ocean CO_2 uptake



Friedlingstein et al., Global Carbon Budget 2020 (Earth Sys. Sci. Data. 2020)

Airborne-based Monitoring

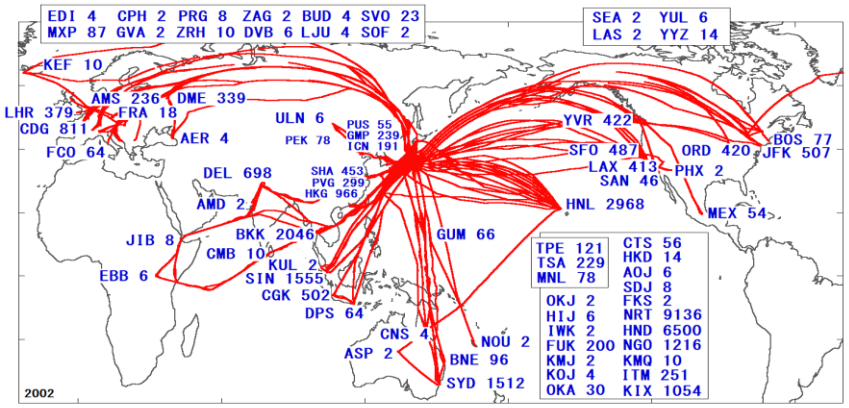
CONTRAIL（Comprehensive Observation Network for TRace gases by AIrLiner）



Continuous CO_2 Measuring Equipment

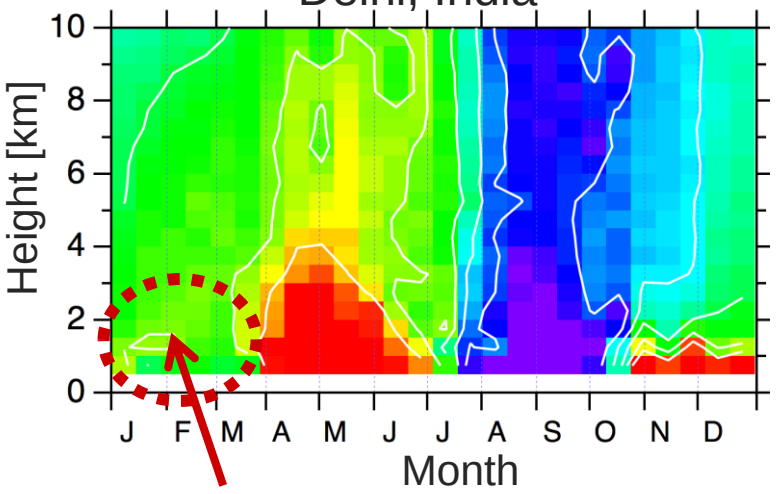
Automatic Air Sampling Equipment

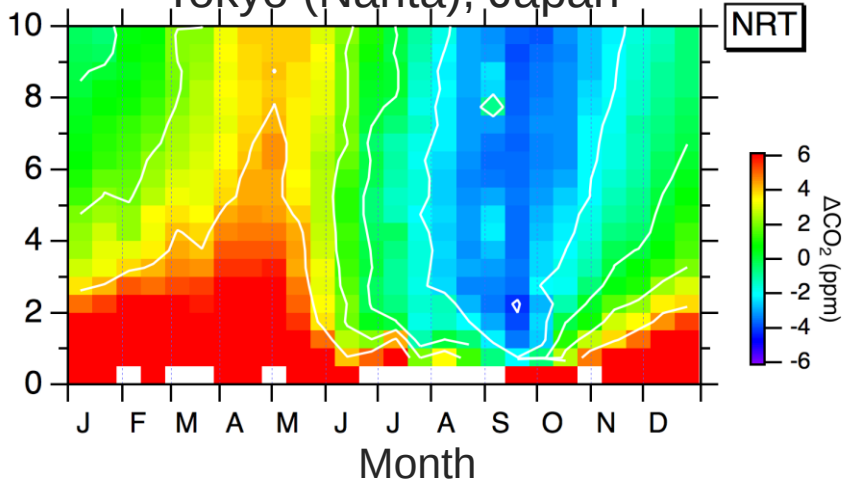
Boeing 777 aircraft and two research equipment



Powerful high-density data for verifying surface fluxes

Vertical distribution of CO_2 concentration and its seasonal change





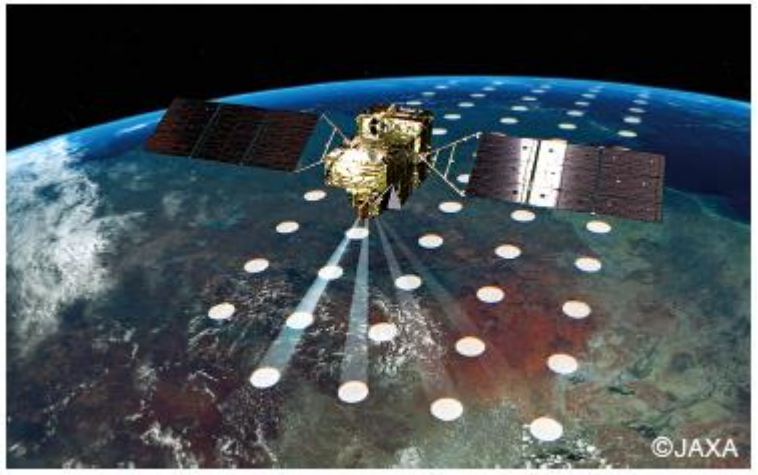
Umezawa et al. *GRL* (2016)
Umezawa et al. *ACP* (2018)

← Flight paths and the number of vertical profile observations of CME

Data: Atmospheric CO_2 mole fraction data of CONTRAIL-CME:
http://www.nies.go.jp/doi/10.17595/20180208.001-e.html

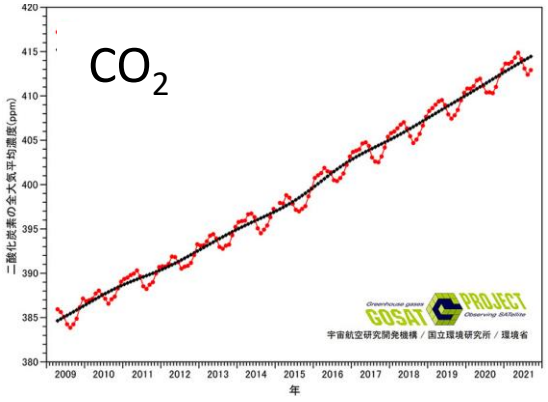
Satellite-based Monitoring

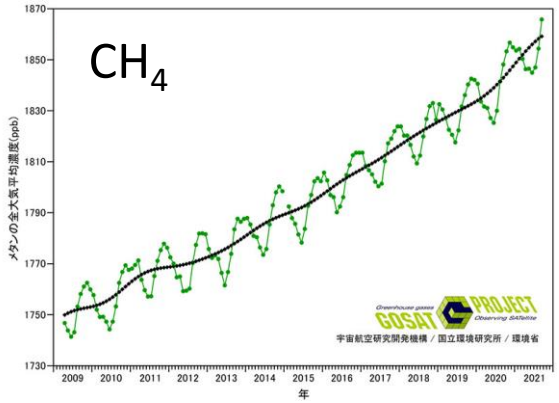
GOSAT



GOSAT-2

Whole-atmosphere monthly mean CO_2 and CH_4 concentrations based on GOSAT observations



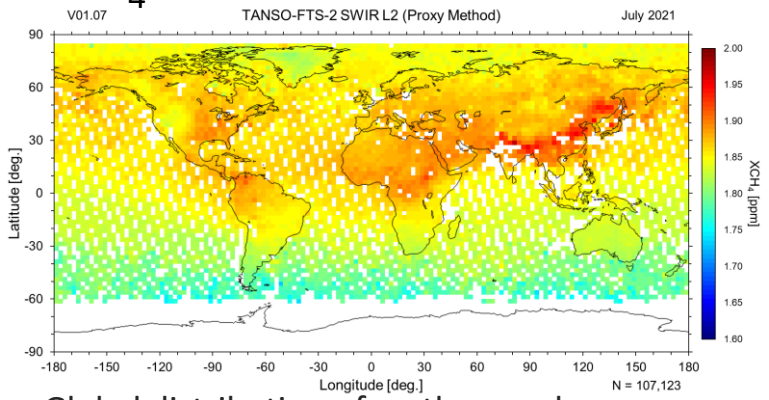


Data:

GOSAT Data Archive Service (GDAS)
https://data2.gosat.nies.go.jp/index_en.html

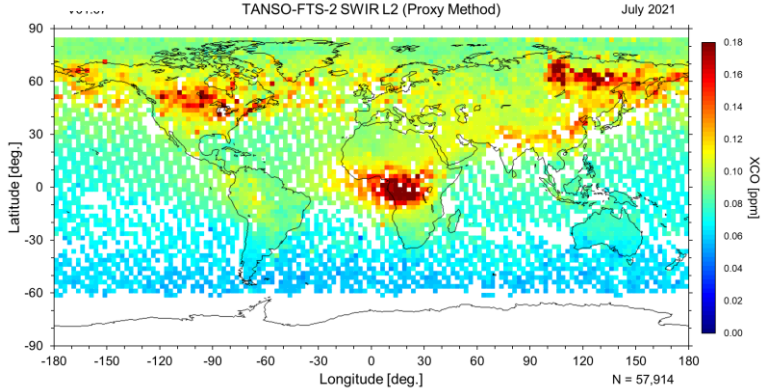
GOSAT-2 Product Archive
https://prdct.gosat-2.nies.go.jp/en/index.html

XCH_4



Global distribution of methane column-averaged dry-air mole fraction (XCH4) retrieved by the proxy-method from FTS-2 data acquired in July 2021.

XCO



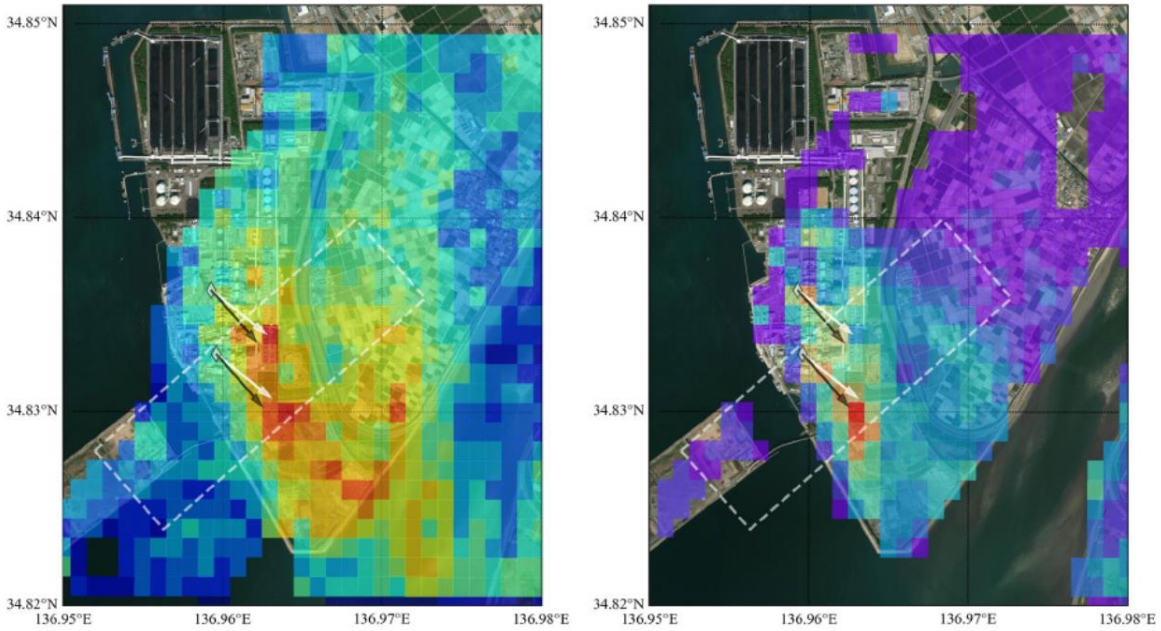
Global distribution of carbon monoxide column-averaged dry-air mole fraction (XCO) retrieved by the proxy method from the FTS-2 data acquired in July 2021.

Observation of CO_2 Emission Sources by Next-Generation Satellites

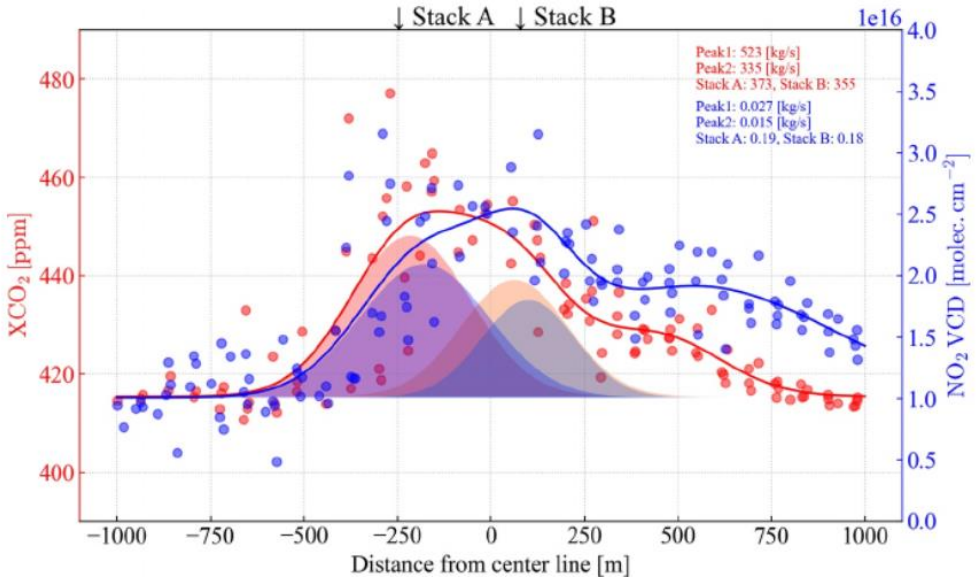
GOSAT-GW: Research development

衛星観測センター
Satellite Observation Center

According to aircraft observations conducted over an actual thermal power plant the estimation accuracy of CO_2 emissions was improved by a factor of three using both CO_2 and NO_2.



Mesh plots of the VCD_{NO2} (left panel) and XCO2 (right panel) retrieved during 11:55:00-12:14:00 (JST).



Cross-sectional plume of emitted XCO_2 (red) and VCD_{NO2} (blue) perpendicular to the wind direction 400m away from the middle point between the two stacks. A horizontal axis represents the distance from a center line (m).

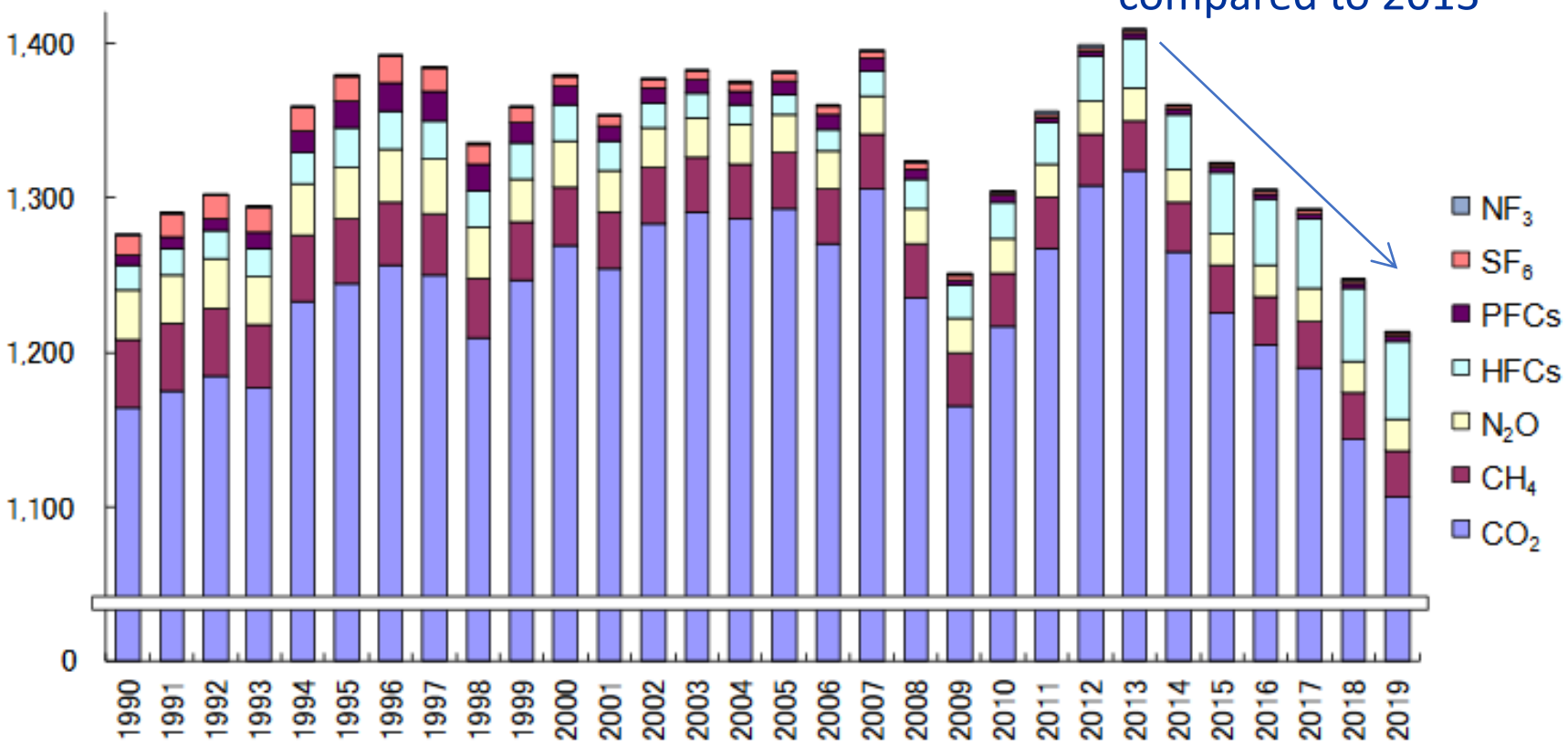
Fujinawa et al. *GRL* (2021)

(Press release in Japanese) https://www.nies.go.jp/whatsnew/20210720/20210720.html

Bottom-up GHG Inventory

Japan's national GHG emissions, 1990–2019: GHG Inventory Office (GIO), NIES

Total GHG emissions by gas
(Million tonnes of CO_2 eq.)



Factors for the decrease in emissions in FY2019:

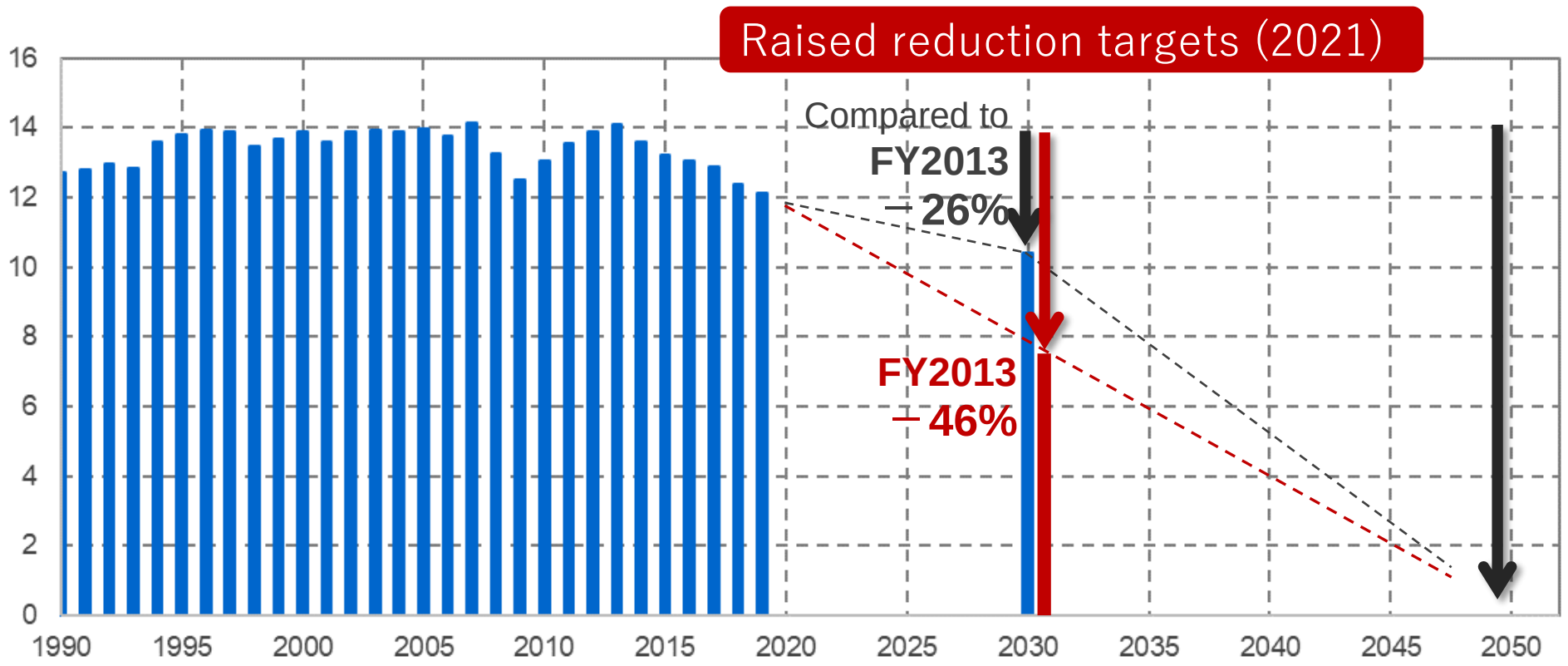
- ✓ Decrease in energy related CO_2 emissions
  - ← Low carbon electricity
  - ← Reduced energy consumption

Press release (Dec 9, 2020): Japan's National Greenhouse Gas Emissions in Fiscal Year 2019 (Preliminary Figures)

https://www.nies.go.jp/whatsnew/20201208/20201208.html

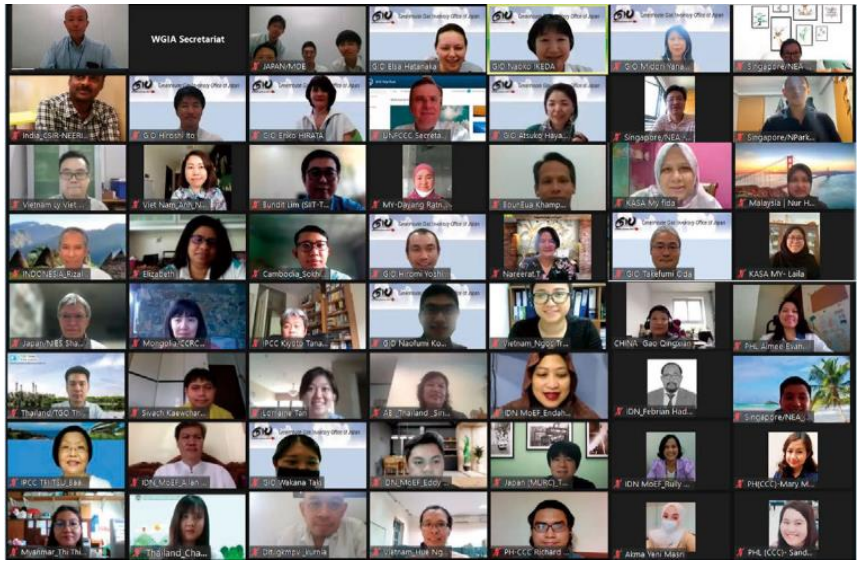
Japan's national GHG emissions, 1990–2019: GHG Inventory Office (GIO), NIES

Total GHG emissions by gas
(100 Million tones of CO_2 eq.)



Workshop on Greenhouse Gas Inventories in Asia (WGIA)
GHG Inventory Office (GIO), NIES

- To improve the accuracy of GHG inventories in Asia
- To provide an opportunity for countries & regions to cooperate and share information related to the development of GHG inventories.

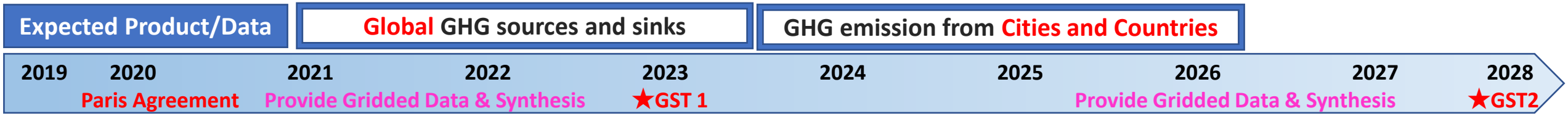


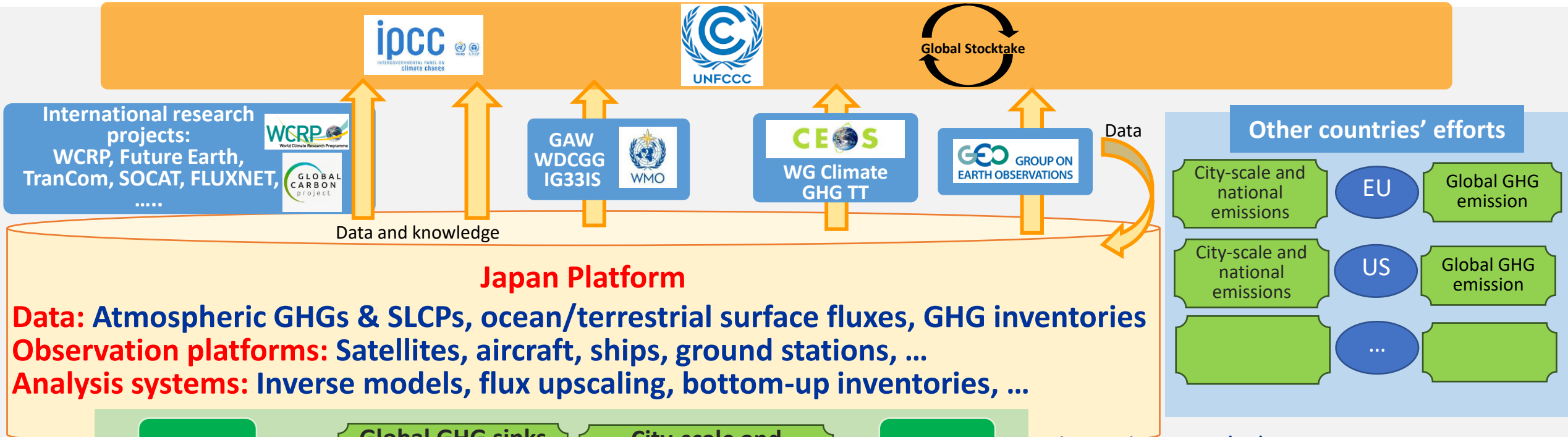
The 18th Workshop on Greenhouse Gas Inventories in Asia (WGIA 18)
July 8-14, 2021, Online

Participants: Government officials and experts engaged in GHG inventories
Supported by the Ministry of the Environment Japan and GIO NIES

https://www.nies.go.jp/gio/en/wgia/index.html

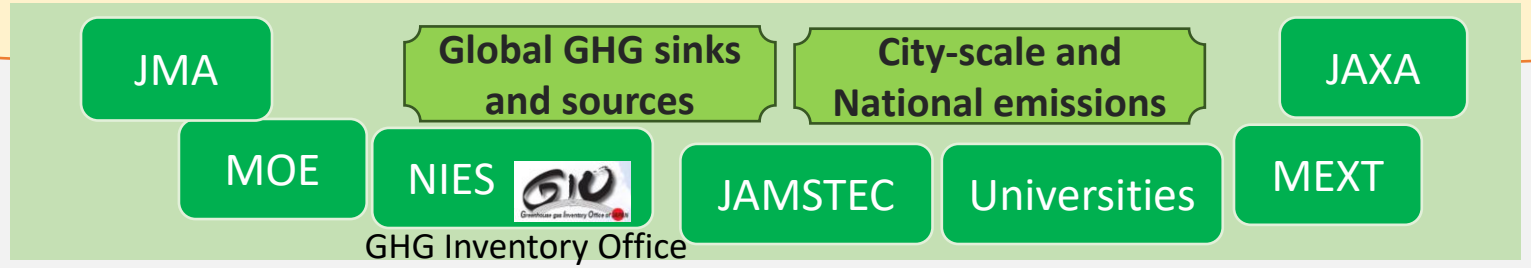
Collaboration Among Japanese Agencies and Institutions to Contribute to the Global Stocktake (tentative)





Japan Platform

Data: Atmospheric GHGs & SLCPs, ocean/terrestrial surface fluxes, GHG inventories
Observation platforms: Satellites, aircraft, ships, ground stations, …
Analysis systems: Inverse models, flux upscaling, bottom-up inventories, …



Discussion needed:

- Uncertainties in various global datasets
- Separation of anthropogenic and natural emissions
- Possibilities of near-future prediction

Summary

- Institutions and communities of GHG observation and analysis need to cooperate to improve up-to-date analysis systems and data coverage globally and in Asia–Oceania (including cities) for better estimation of the distribution of **anthropogenic and natural sinks and sources** with sufficient accuracy
- Urgent international cooperation is needed to improve reliability in the global datasets
- Technological development is still required for
  - separation of anthropogenic and natural emission
  - near-future prediction of impacts of mitigation actions