Detecting Anthropogenic CO_2 Emissions from Mega-City Regions from Space by "IBUKI" (GOSAT)

September 1st, 2016

Ministry of the Environment, Japan
National Institute for Environmental Studies
Japan Aerospace Exploration Agency

The Greenhouse gases Observing SATellite (GOSAT) "IBUKI", developed jointly by the Ministry of the Environment (MOE), the National Institute for Environmental Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA) is the world's first satellite designed specifically to monitor greenhouse gases from space. The satellite has continued to fulfill its main mission to monitor atmospheric carbon dioxide (CO_2) and methane (CH_4) concentrations from space since its launch in January 2009.

Anthropogenic CO_2 concentrations in mega-cities including the metropolitan area in Tokyo were analyzed for the five and half years from June 2009 to December 2014, based on the observational data acquired by "IBUKI".

It was found that the anthropogenic CO_2 concentrations estimated from "IBUKI" data generally agree with those estimated using data on fossil fuel emissions (inventory) in Japan. These results indicate that satellite observations from space can become useful to monitor and verify CO_2 emission rates that were aggregated and published by all nations of the world based on the framework of "The Paris Agreement".

With the progress in satellite data collection and further improvement in data analysis methods, these observational data by "IBUKI" and its successor (GOSAT-2) accumulated over multiple years will be compared with emission inventories.

Global mean atmospheric CO_2 levels have increased from about 280 ppm in pre-industrial times to 400 ppm at the present time. The increase of CO_2 concentrations is caused mainly by anthropogenic activities associated with fossil fuel combustion which is strongly localized at fossil fuel power plants and mega-city regions. Moreover, the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) reached a historical agreement, "The Paris Agreement", in December 2015, which requires all nations to accelerate and intensify the actions and investments needed for a sustainable low-carbon future. To achieve these goals, it is essential to monitor and precisely evaluate greenhouse gas emission rates resulting from human activities.

Our previous press release in December 2014 showed the potential of satellite observations to detect greenhouse gas emissions from fossil fuel combustion from space. This time, "IBUKI" observations for five and half years (June 2009 – December 2014) were analyzed with improved analysis methods.

The spatiotemporal distribution of anthropogenic CO_2 concentrations derived from the observational data acquired by "IBUKI" is shown in Figures 1 and 2. Regions with high anthropogenic CO_2 concentrations can be identified as those with dense populations or industrial zones with fossil fuel power plants and developments of oil and gas fields in North America, Europe, Middle East, India, and China. Additionally, the observational data collected during these five and half years enable us to detect areas with high anthropogenic CO_2 concentrations in the Kanto area, Japan.

Figure 3 shows the relationships between anthropogenic CO_2 concentrations derived from emission inventories and those derived from "IBUKI" data in four regions: the globe, North America, South to East Asia, and Japan. Table 2 shows the differences of the regression lines between previous and present results. Key aspects are as follows:

1. Anthropogenic CO_2 concentrations derived from emission inventories and the observational data acquired by "IBUKI" show higher correlations and lower differences compared with those of previous results.
2. High correlations are found in the concentrations around the globe, North America, and South to East Asia, and the differences in concentrations decrease within the range of observational error for "IBUKI".
3. Whereas no correlation was found for Japan in previous analyses with fewer observational data, we found correlations for Japan in the present analysis, thanks to the observational data collected during these five and half years. However, further improvements are necessary in the methodology of data analysis, the volume of observational data, and the accuracy of satellite observations to analyze anthropogenic CO_2 emissions at national levels.

The present estimates demonstrated the potential utility of observations by “IBUKI” and its successor (GOSAT-2) to monitor anthropogenic CO_2 emission rates that all nations are required to publish based on “The Paris Agreement”. The methodology to improve both the frequency and net volume of observational data will be further investigated to improve the accuracy of estimates of anthropogenic CO_2 concentrations. Additionally, further studies and evaluations, for example, ground-based observations in the surrounding of large emission sources, will be implemented to refine estimates of anthropogenic emission rates from CO_2 concentration measurements acquired by satellites.

[Contact Information]
About GOSAT data and analysis results:
GOSAT Project, Satellite Observation Center,
National Institute for Environmental Studies (NIES)
Phone: +81-29-850-2035 (English)

About GOSAT, onboard sensors, and observation status: Masakatsu Nakajima
JAXA Space Technology Directorate I
GOSAT-2 Project Team
Phone: +81-50-3362-6130

Table 1. List of regions indicating high anthropogenic CO_2 concentrations derived from "IBUKI" in Figures 1 and 2.

No.	Rough range of the region for high concentrations of anthropogenic CO_2 emissions derived from "IBUKI"	Countries, regions or major cities in the region	Maximum value of the concentrations of anthropogenic CO_2 emissions for the region (1 deg. × 1 deg., in 5.5 years)
1	Latitude: 33 – 46 N Longitude: 114 – 127 E	China: Zhangjiakou, Anshan, Harbin, and Tianjin	6.2 ppm
2	Latitude: 20 – 23 N Longitude: 84 – 89 E	India: Kolkata (Calcutta)	2.1 ppm
3	Latitude: 40 – 41 N Longitude: 67 – 73 E	Eastern part of Uzbekistan, Southern edge of Kazakhstan, Eastern area of Kyrgyzstan, Northern edge of Tajikistan	2.8 ppm
4	Latitude: 30 – 32 N Longitude: 37 – 38 E	Northern part of Saudi Arabia, Jordan	2.1 ppm
5	Latitude: 38 – 41 N Longitude: 79 – 83 W	The United States: Pittsburgh	2.1 ppm
6	Latitude: 33 – 35 N Longitude: 114 – 119 W	The United States: Los Angeles	3.5 ppm
7	Latitude: 17 – 19 N Longitude: 99 – 102 W	Mexico: Acapulco	2.7 ppm
8*	Latitude: 35 – 37 N Longitude: 139 – 141 E	Japan : Tokyo and Its Vicinity	0.5 ppm

*As for Japan, a different method was used to derive the maximum value due to its small number (5 - 14) of data per 1 degree x 1 degree grid.

Table 2. Comparisons of the number of observational data and the slopes of regression lines in Figure 3 for four regions: the globe, North America, Southeast Asia, and Japan.

	Previous Result: Period : 2009 - 2012		Present Result: Period : 2009 - 2014	
	Number of data	Slope	Number of data	Slope
The Globe	8315	1.21 ± 0.21	13616	1.08 ± 0.13
North America	3011	1.05 ± 0.38	4684	0.99 ± 0.28
South - East Asia	3243	1.22 ± 0.32	5589	0.99 ± 0.17
Japan	262	0.81 ± 1.42	396	0.95 ± 0.79

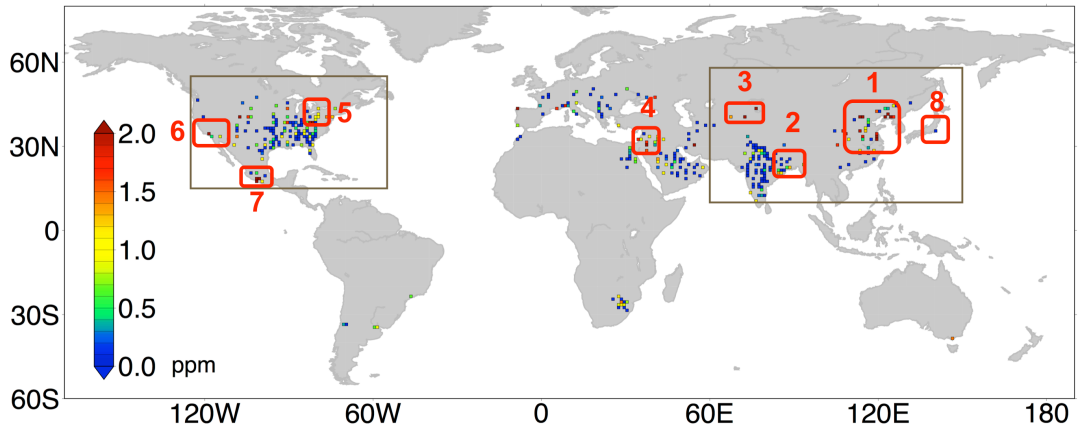

Figure 1. Distribution of anthropogenic CO_2 concentrations estimated from observational data acquired by "IBUKI" (1° grid; only grids with more than 24 observational data points are plotted). Anthropogenic CO_2 concentrations are shown in colors.

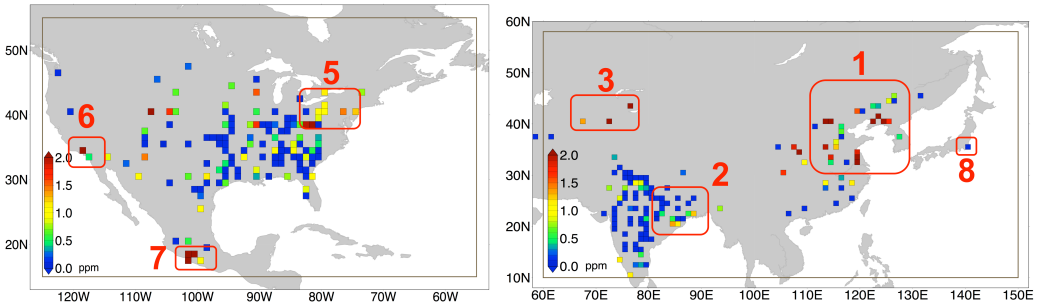

Figure 2. Enlarged views of North America (left) and South to East Asia (right) in Figure 1.

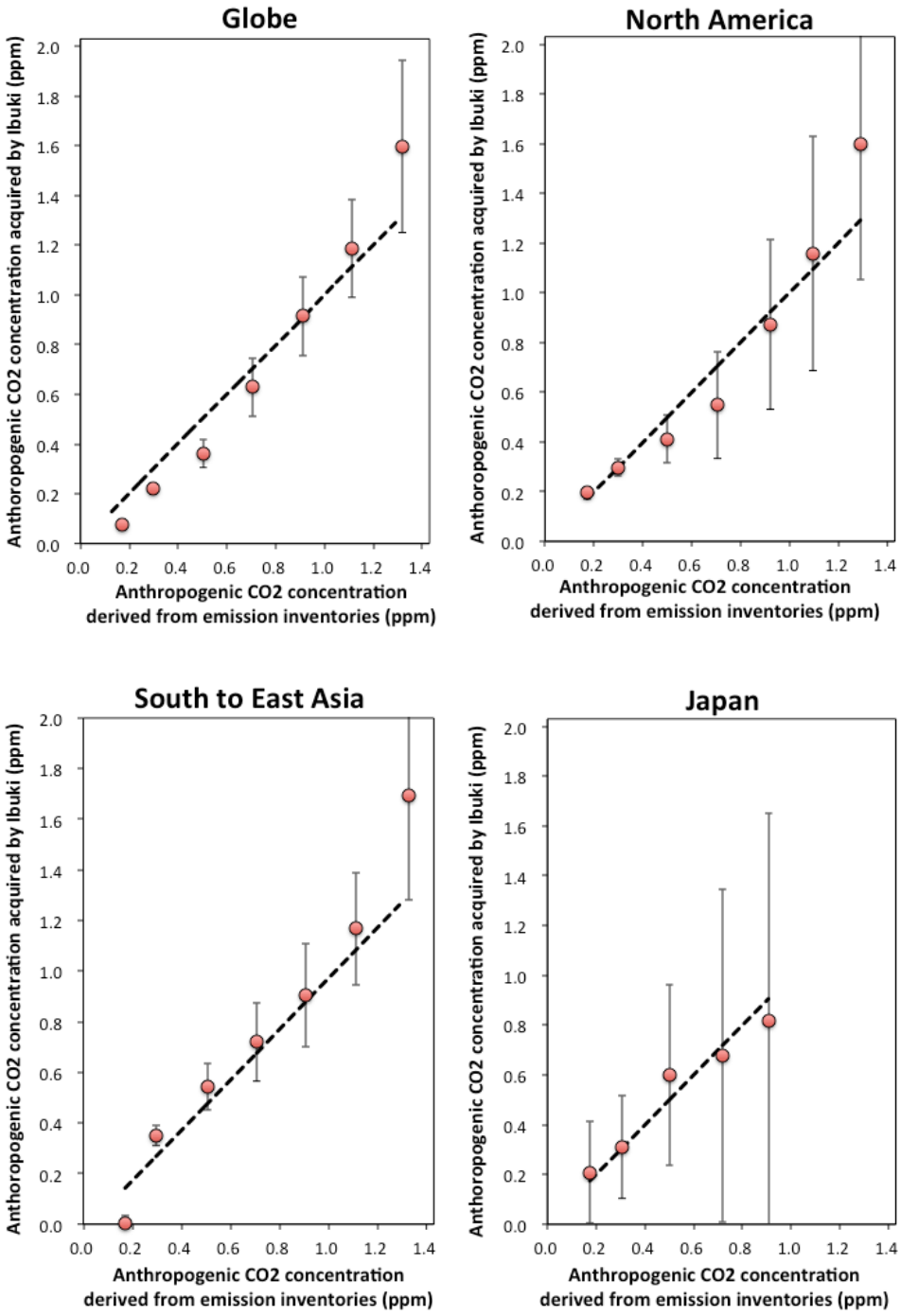

Figure 3. Relationships between anthropogenic CO_2 concentrations derived from emission inventories and those acquired by "IBUKI" for the globe (top-left), North America (top-right), South to East Asia (bottom-left), and Japan (bottom-right). Anthropogenic CO_2 concentrations were classified for each 0.2 ppm of concentrations from the inventories and then averages and standard deviations were calculated in each class. Broken lines show the relationship of 1:1 between the concentrations from inventories and those from "IBUKI". This study excluded data with concentrations from inventories greater than 1.4 ppm (1.0 ppm for Japan).