Joint Submission to the first Global Stocktake: Real-time anthropogenic emission observations from Japanese passenger aircrafts in support of the monitoring of the climate mitigation progress

The Japan Aerospace Exploration Agency (JAXA), ANA HOLDINGS INC.(ANAHD), and the Institute for the Global Environmental Strategies (IGES) are pleased to submit an input to the Global Stocktake of the Paris Agreement in response to the mandate of Decision 19/CMA.1, paragraph 19, 36 and 37. This submission provides inputs to a cross cutting guiding question 30[1]:

Summary

- Real-time observation of local emissions of CO_2 can inform local mitigation actors of the progress of their mitigation actions and can assist them to enhance the effects and ambition of those actions in a timely manner. This is complementary to the information of CO_2 inventories, which are estimates of CO_2 emissions and removals only periodically, e.g., annually. In addition, visualizing the observation results can help a wide range of stakeholders (e.g., citizens) intuitively understand the trends of emissions from the local community. Therefore, it can motivate them to drive their efforts to mitigate climate change.
- JAXA has developed a remote sensing technique that can be operated on a commercial passenger aircraft, and JAXA and ANAHD. have started a new project called the Greenhouse gas Observations of Biospheric and Local Emissions from the Upper sky (GOBLEU). The GOBLEU instrument collects CO_2, nitrogen dioxide (NO_2) and Solar-Induced Fluorescence (SIF) data. NO_2 is one of major air pollutants co-emitted with CO_2 via fossil fuel combustion. NO_2 data should enables us to depict spatial patterns of anthropogenic CO_2 emissions over major populated and industrialized areas and attribute the emissions to specific sources, such as industries and traffic.
- The GOBLEU project has completed several test flights and collected NO_2 data over major populated and industrialized areas. The NO_2 data showed timely snapshots of NO_2 spatial distributions, suggesting the utility of NO_2 data as a proxy for anthropogenic CO_2 emissions that should enhance emission estimations and attribution ability.
- The GOBLEU instrument can be operated in almost any passenger aircraft without any

[1] What additional information is needed to enhance ambition, both of actions to take and support needed to achieve the long-term goals of the Paris Agreement, including by enhancing international cooperation for climate action?

modifications. Compared to other observation techniques, such as the ground-based monitoring system, the GOBLEU operation requires less technical skill and it is inexpensive. JAXA is willing to promote the observation technique by expanding the observation coverage and partnership to other countries through enhancing international cooperation under the Paris Agreement.

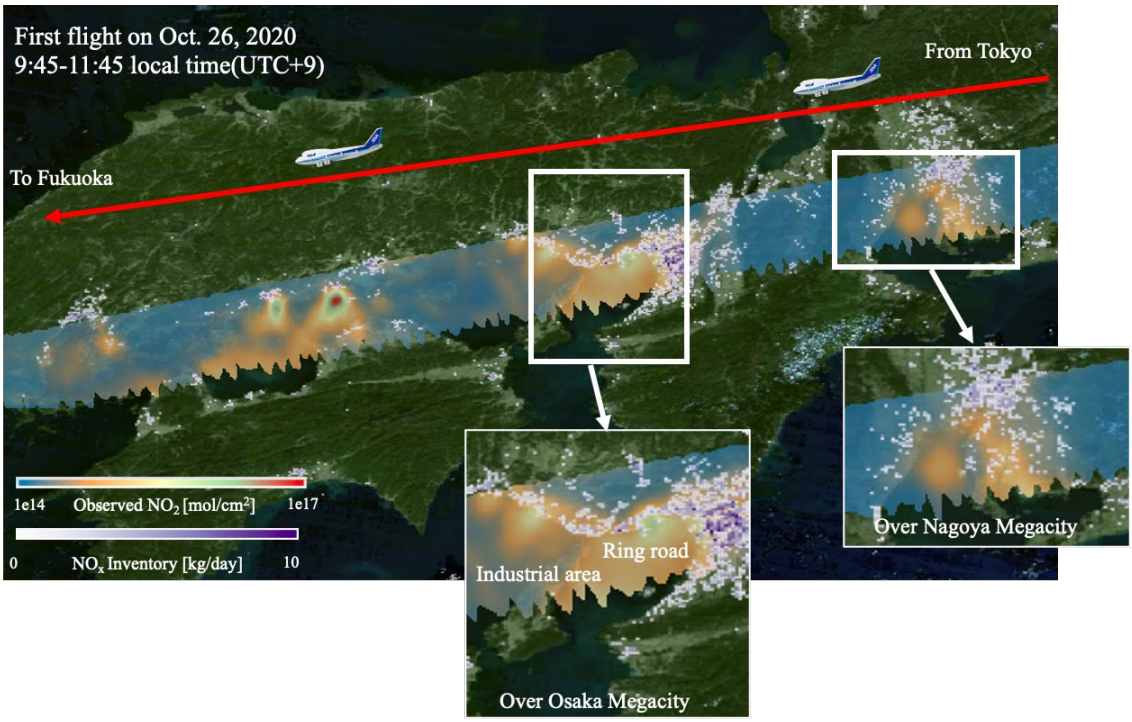


Figure 1. The first GOBLEU flight collected NO_2 data as emission proxy for CO_2 emissions in October 2020. NO_x inventory estimates[2] are superimposed on the observed NO_2 map for indicating local transportation source areas (purple dots).

[2] Formulation Committee for PM2.5 Emission Inventory and Source Profile, "PM2.5 Emission Inventory and Source Profile", 2019, 600 pp. 380. (in Japanese)

Table 1. A summary of GOBLEU observation

Items	**GOBLEU contributions**
Emissions and removals covered	Subnational ~ city
Indicator for CO_2 emissions and removals	Nitrogen Dioxide (NO_2) for emissions (anthropogenic); Solar induced fluorescence (SIF) for emissions/removals (anthropogenic/natural)
Period	Nov. 2020 (demonstration)-
Operational flight route	Tokyo-Fukuoka, Tokyo-Wakkanai/Hokkaido
Spatial resolution	sub-km Instantaneous ground field of view (IGFOV)
Observation frequency*	Every 0.5 sec

1. Methodology

The Japan Aerospace Exploration Agency (JAXA) and the ANA HOLDINGS INC.(ANAHD) launched a new project called the Greenhouse gas Observations of Biospheric and Local Emissions from the Upper sky (GOBLEU), which conducts airborne remote sensing from an ANA passenger aircraft and collects CO_2, NO_2, and SIF data to contribute to the climate mitigation monitoring.

One of the challenges in anthropogenic CO_2 emission estimation from atmospheric data is disentangling anthropogenic and natural CO_2 emissions. NO_2 is often co-emitted with CO_2 in fossil combustion. NO_2 can serve as a proxy for fossil fuel CO_2 emissions and improve our ability to detect and estimate anthropogenic CO_2 emissions in the presence of other CO_2 contributions. SIF can serve as an indicator of CO_2 removals due to photosynthetic activities by plants.

GOBLEU prototypes multi-species observations and provides direct technical and scientific implications to the proposed use of CO_2, NO_2, and SIF data to improve CO_2 emission estimation. JAXA developed an imaging spectrometer as small as carry-on luggage to collect high spatial resolution[3] spectra of NO_2 (420-490 nm), CO_2 (1560-1640 nm), and SIF (670-780 nm). SIF should indicate the plant production level (carbon removals) of the terrestrial biosphere (e.g., forests and other vegetated areas) with a moderated spectral resolution during domestic passenger flights.

Three modules are coupled with optical fibers to relay the solar light reflected the Earth's surface, packaged in two pieces of luggage and occupying two passenger seats. The GOBLEU instrument are easily mounted on a passenger seat without modifications. The "passenger" instrument can complete all the inspections required to be on board before gate arrival. The instrument images are shown in Fig. 2.

[3] ~100 m along track spatial resolution and 10 times higher spatial resolution than the start of art satellite remote sensing

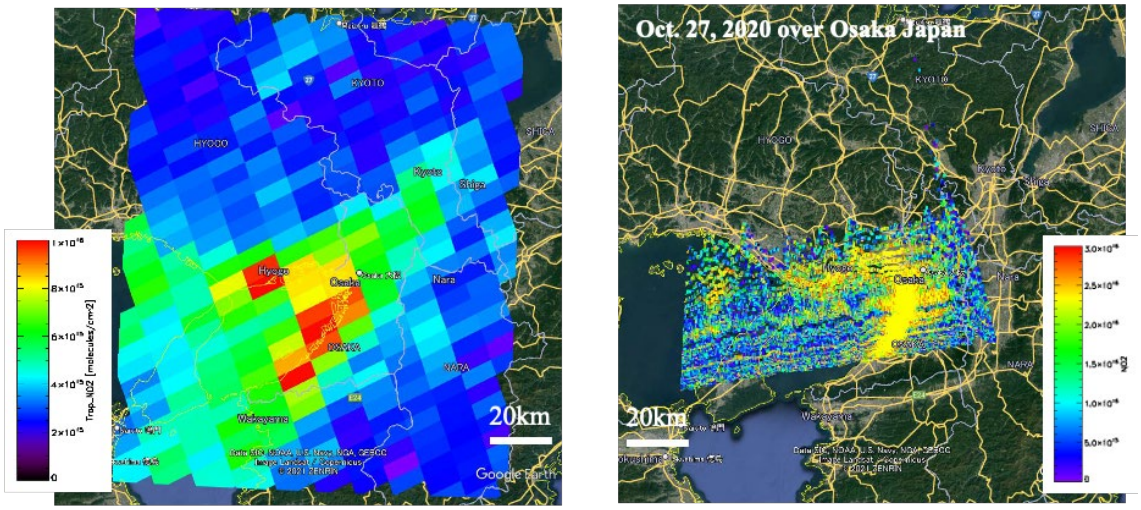
2. Results

In October 2020, we conducted the first high-resolution multi-species (CO_2 and NO_2) observations from Japanese passenger aircraft on one of ANAs domestic flight routes (Tokyo-Fukuoka). The observational area from Tokyo to Fukuoka city generates approximately 30% of Japan's total CO_2 emissions. The two-hour flight allowed us to collect data ranging from 130° E to 140° E in longitude and 33.5° N to 36° N in latitude (also in about 900 km). The data were collected every 0.5 s (nominal) and created up to 5 million data points during the single flight. The observed NO_2 spatial distribution is presented in Fig. 1. with the NO_x emission inventory map. Comparing our data with the emission inventory map, the obtained data depicted spatial patterns of NO_2 concentrations over the cities and industrial areas, which highly correlated with emission sources.

Figure. 3 presents a comparison between the satellite observations of NO_2 and GOBLEU over the Osaka megacity. The spatial resolution sizes of the state-of-the-art satellite observation, which achieved by TROPOMI, was 7 km x 7 km for each observation. As shown in Fig. 3, GOBLEU data has finer spatial resolution than TROPOMI observations; GOBLEU data can indicate the NO_2-enhanced region. Especially, GOBLEU can detect transportation emissions along the road, while current satellite observations are challenging.

After the COVID-19 pandemic, the observation flights will be conducted on other routes like Tokyo-Wakkanai/Hokkaido. Future GOBLEU flights also plan to collect SIF data. The Tokyo-Wakkanai/Hokkaido flight route should be ideal for collecting SIF data over Japan's densely forested northeast area.

Figure 2. The GOBLEU remote sensing equipment onboard an ANA passenger aircraft.



TROPOMI NO_2,
Local time 11:11 (UTC+9)

GOBLEU SCD_NO_2,
Local time 13:15 (UTC+9)

Figure 3. Emission proxy NO_2 data over the Osaka megacity collected by ESA's TROPOMI satellite (left) and GOBLEU (right). Note that two observations were not made at the same time. The color scales for the two plots are different.

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4. Reference

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