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City-level CO_2, CH_4, and NO_2 observations from Space: Airborne model demonstration over Nagoya

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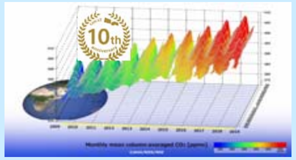
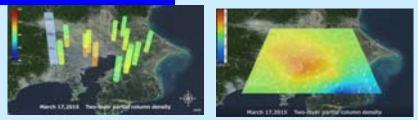
The Thermal And Near infrared Sensor for carbon Observation Fourier-Transform Spectrometer (TANSO-FTS) onboard the Greenhouse gases Observing SATellite (GOSAT) launched in Jan. 2009 has demonstrated accurate and precise CO_2 and CH_4 distribution measurements from space. The globally acquired data have contributed to reduce the uncertainties in global and regional flux inverse estimates. In response to the urgent need for monitoring carbon emissions from intense localized sources, such as cities and power plants, we have been developing a next generation instrument that should be able to detect and map plumes from the intense sources with a 1km spatial resolution. We design our system to implement both targeted observations for intense local sources with high spatial resolution and wide-swath observations for covering the earth's entire surface with 2-axes pointing system and two telescopes. We have developed airborne imaging spectrometer suites with three imaging spectrometers: 0.47 µm for nitrogen dioxide (NO_2), 0.76 µm for oxygen (O_2) and solar-induced chlorophyll fluorescence (SIF) and 1.6 µm for carbon dioxide (CO_2) and methane (CH_4). The airplane observations successfully recorded CO_2 and NO_2 enhancements over a power plant in Greater Nagoya Area. In our presentation, we will present our first emission estimates based on the simultaneous CO_2 and NO_2 observation.

Lessons leaned from a decade long GOSAT observation

Thermal And Near infrared Sensor for carbon Observation Onboard GOSAT



https://data2.gosat.nies.go.jp/gallery/fts_l3_swir_co2_gallery_en.html



GOSAGT can target up to 13 points over great TOKYO and provide partial column density of LT and UT from SWIR and TIR <too sparse and uncertain wind data>

<Demonstrated from decade long observation>

- Accurate and precise CO_2 (1.6 ppm (0.4 %)) CH_4 (13 ppb (0.7 %)) distribution measurements from space.
- Reduce the uncertainties in global and regional flux inverse estimates

<To do>

Urgent needs for monitoring carbon emissions from intense localized sources, such as cities and power plants to contribute to the global stocktake of the Paris Agreement.

$$Flux_{CO_2} = \frac{V*airmass}{radius} \Delta X CO_2$$

$Flux_{CO2}$: CO_2 local flux (emission)

How to increase ΔCO2 : much smaller foot print

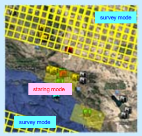
How to improve accuracy: select upwind reference

V : Wind speed: Model has large uncertainty

Air mass: optical path from O_2A band

Air-borne model for next generation space measurement

1. Higher spatial resolution data enhance the column density.
2. Closer upwind reference can remove background and inflow.
3. Short lived tracer such as NO_2 proved related information on wind direction and speed.
4. Imaging capability can detect an emission from different source sectors

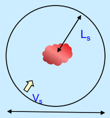


Survey entire earth's surface

Selecting Proper reference

Staring 1 km resolution will enhance dCO_2 and dCH_4

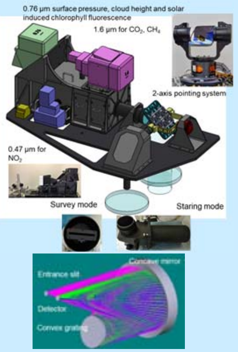
- Image can detect plume and has closer reference
- Estimate plume direction



10.5 km
(large footprint)

Item	NO_2	O_2 A and SIF	CO_2 and CH_4
Spectral coverage	420-490 nm	747–783 nm	1.56–1.67 µm
Spectral resolution	8 Å	0.9 Å	2 Å
Detector	Si	Si	InGaAs cooled at +10℃ by thermoelectric cooler
Pixel number and size	2048 by 2048 pixels, 6.5 µm by 6.5 µm	2048 by 2048 pixels, 6.5 µm by 6.5 µm	640 (spectra) by 512 pixels (cross track) 20 µm by 20 µm
Integration time	0.5 sec (typical)	0.5 sec (typical)	0.5 sec (typical)

solar-induced chlorophyll fluorescence (SIF)



Modular Design

Littrow Configuration: limiting spectral coverage

Compact: collimating and correcting

High efficiency=very low polarization sensitivity against highly polarized input scattered light by the earth's atmosphere

Common design for both V, NIR, and SWIR

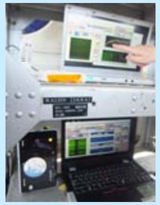
Flight over greeter Nagoya

1. Observation needs for Both global flux and local flux from individual source sector by remote sensing
2. Modules of 2 telescopes, pointing mechanism, 3 spectrometers to detect and map plumes from the intense sources with a 1 km spatial resolution were assembled.
3. Our first emission estimates based on the simultaneous CO_2 and NO_2 observation over greater Nagoya

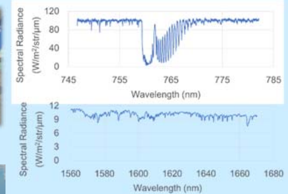
Different GHG source sector location of greater Nagoya

CO_2: Power plant, Traffic, Industry

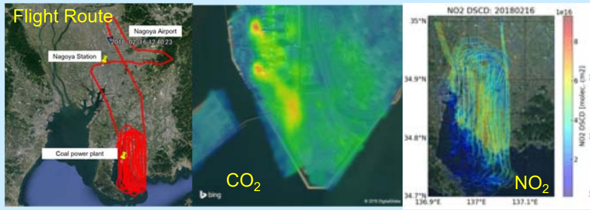
CH_4: Waste water, Liver stock, Gas Production



cruising altitude of 2893 m



Measured absorption spectra of O_2, CH_4, and CO_2. by airborne observation on Feb. 16, 2018



February16,2018, The wind direction and speed at the Nagoya Chubu Airport at noon were northwest and 3 m/s

Next Flight

2020

Feb. 2018

Three independent spectrometers
Moderate res. UV-V spectrometer
(NOT optimized for NOE)

0.76µm for Surface Pressure and SIF

1.6µm for CO_2, CH_4

0.47µm for NO_2

Assembled Upgraded NO_2 spectrometer
Telescope and relay optics

Flux Estimation from a point source

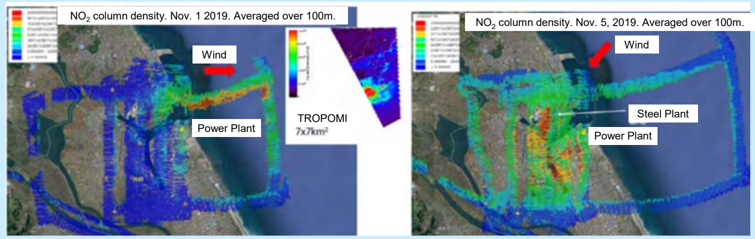
Can NO_2 data provide plume information on wind speed, direction and expansion?

Simultaneous measurements of short-lived tracer NO_2 from the high-temperature combustion of fossil

(1) To identify emissions from different source sectors of CO_2

(2) To provide wind speed and direction from horizontal distribution data

Demonstration flight using NO_2 spectrometer alone before 2020 Nagoya Campaign.



Flight over Kashima Industrial Area on Nov.1, 2019 (wind from west) and Nov. 5 (light wind)

Much more compact system for much Next Flight

Compact UV-V spectrometer on unmanned aircraft on Nov.13 and 17, 2019 at JAXA Taiki Aerospace Research Field (Clean air) courtesy of Muraoka

JAXA EORC : http://www.eorc.jaxa.jp/GOSAT/index_j.html