Quick Look Algorithm for GHG Source Detection by Using Airborne Imaging Spectrometer Suite

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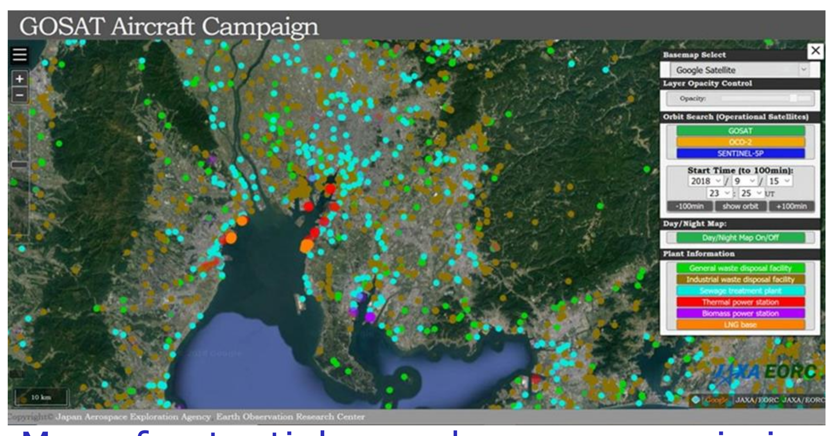
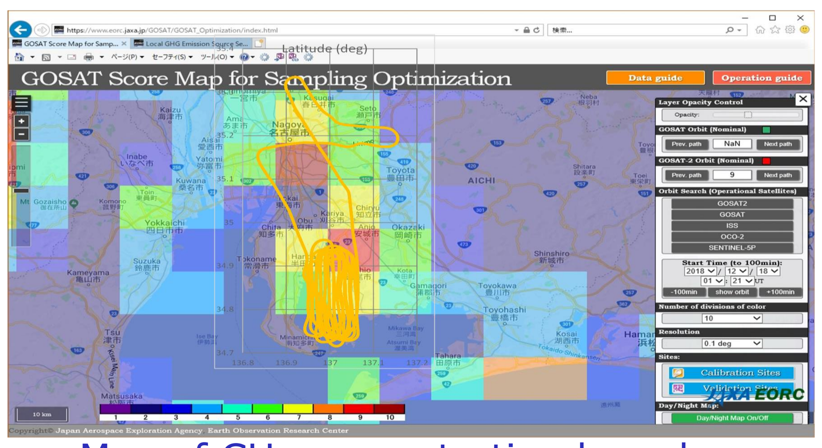
Motivation

In almost Japanese megacities, various CO_2 and CH_4 emission source like industrial activity (power plant, landfills, gas factory, water processing plants), and agricultural activity (rice cultivation, pig farm) are concentrated within a few tens kilometers region. In order to estimate CO_2 and CH_4 emission rate for above various different sources in the medium scale region, airborne remote sensing approach is one of the best methodology with respect to its uniformity and extensiveness compared to in-situ measurement on the ground or by airplane, as well as to its high spatial resolution and sampling frequency compared to space-borne remote sensing.



Map of potential greenhouse gas emission source (around Nagoya region)



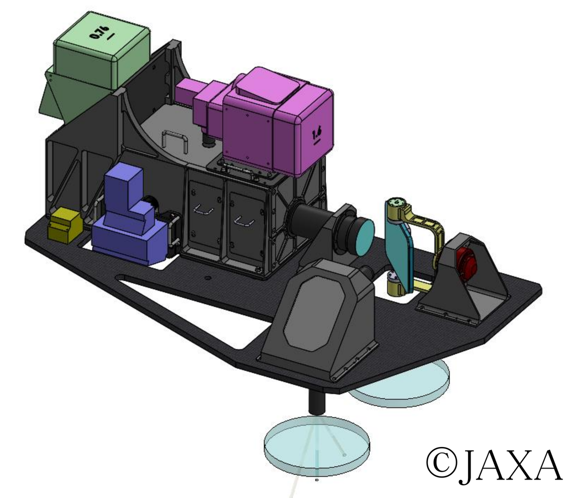
Map of CH_4 concentration based on inventory information

URL: https://www.eorc.jaxa.jp/GOSAT/Local_GHG_Source/index_j.htmla

Instrumental specification

Imaging-spectrometer suites consist of NIR spectrometer for O_2-A band measurement and SWIR spectrometer for CO_2/CH_4 measurement.

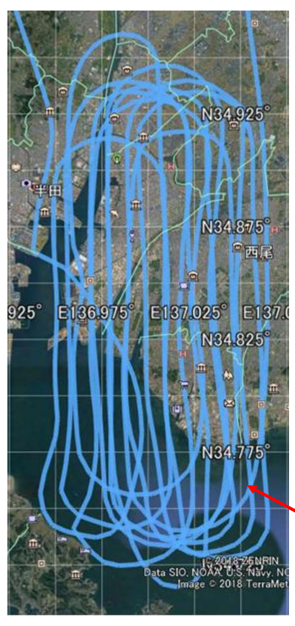
Item	O_2 A and SIF	CO_2 and CH_4
Spectral coverage	747–783 nm (NIR)	1560–1670 nm (SWIR)
Spectral resolution	0.09 nm	0.17nm
GSD (at 2.9km height)	~50m (after binning over 64 pixels)	~40m (after binning over 16pixel)
Swath	~1.6km	~1.3km
Integration time	0.5 sec (typical)	0.5 sec (typical)



Airborne Imaging-spectrometer suites(Courtesy of Kurose)

Flight Experiment

Picture of the airplane and the instrument



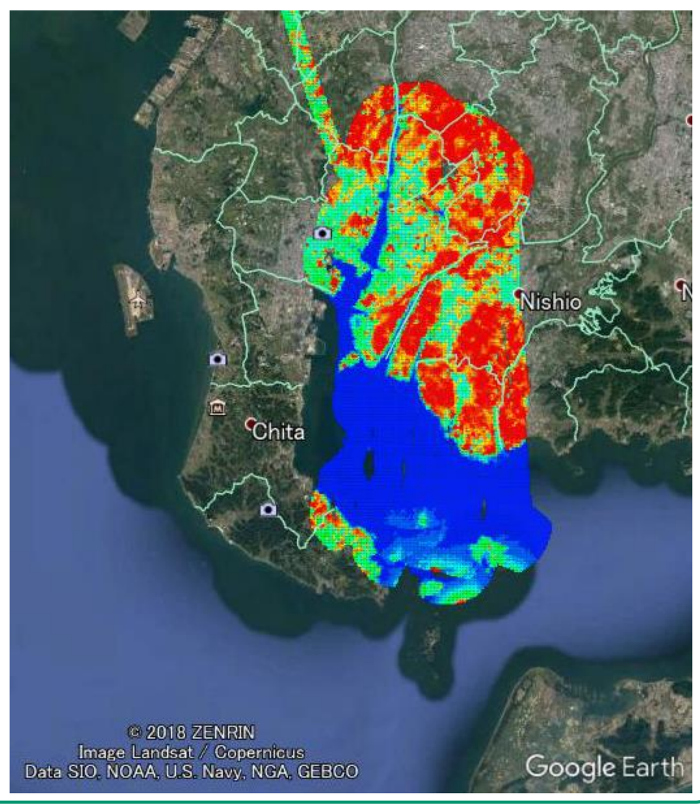
Flight route On Feb. 16,2018

For the first flight, we selected the eastern part of the Nagoya urban area, in which there are large CO_2 emission sources, including a coal power plant and the transportation sector, and possible CH_4 sources from agriculture, energy manufacturing, and waste that are geographically mixed.

Hekinan power plant

Geolocation determination

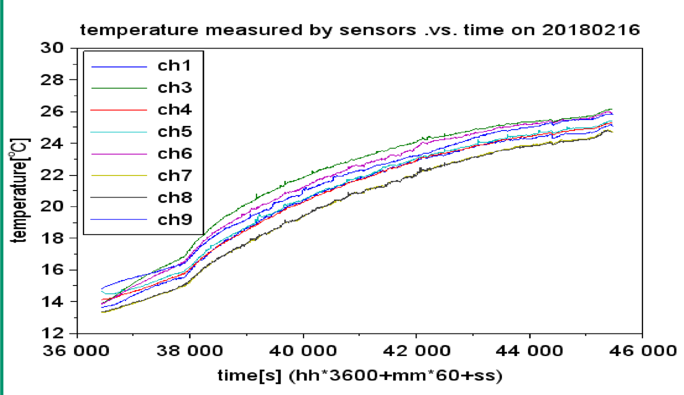
Position and attitude of the airplane were determined by an inertial measurement unit (IMU) and global navigation satellite system (GNSS) receivers. Time stamp of each observation was recorded according to the internal clock of data acquisition PC. In the right side panel, position of the sea coast , river and lake are clearly seen. Urban area can be recognized as dark area since the spectra reflectivity of the surface in SWIR region is low.



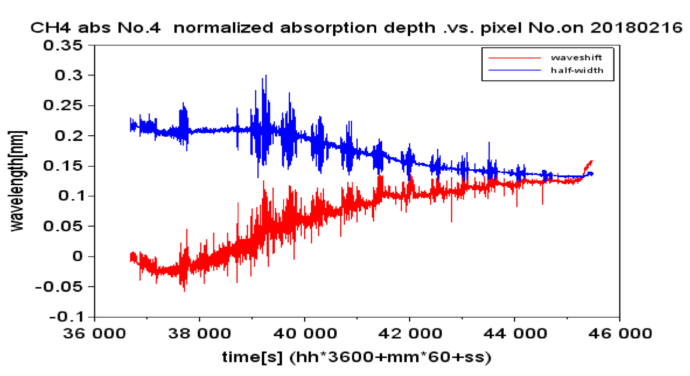
Footprint mapping for the integral intensity over wavelength coverage for each spectrum of the SWIR band.

Quick look algorithm for Spectral Analysis

Instrumental uncertainty



Variation of temperature of the instrument



Variation of half width and center of wavelength of the absorption line

We solved two main problems in determination for column amount by spectral analysis.
The first point is to estimate a baseline without gas absorption. In order to solve the problem, Continuum Interpolated Band Ratio(CIBR) method was adopted. That is to say, a baseline was determine by linearly interpolated from neighboring pixels and normalized spectrum was calculated as follows,

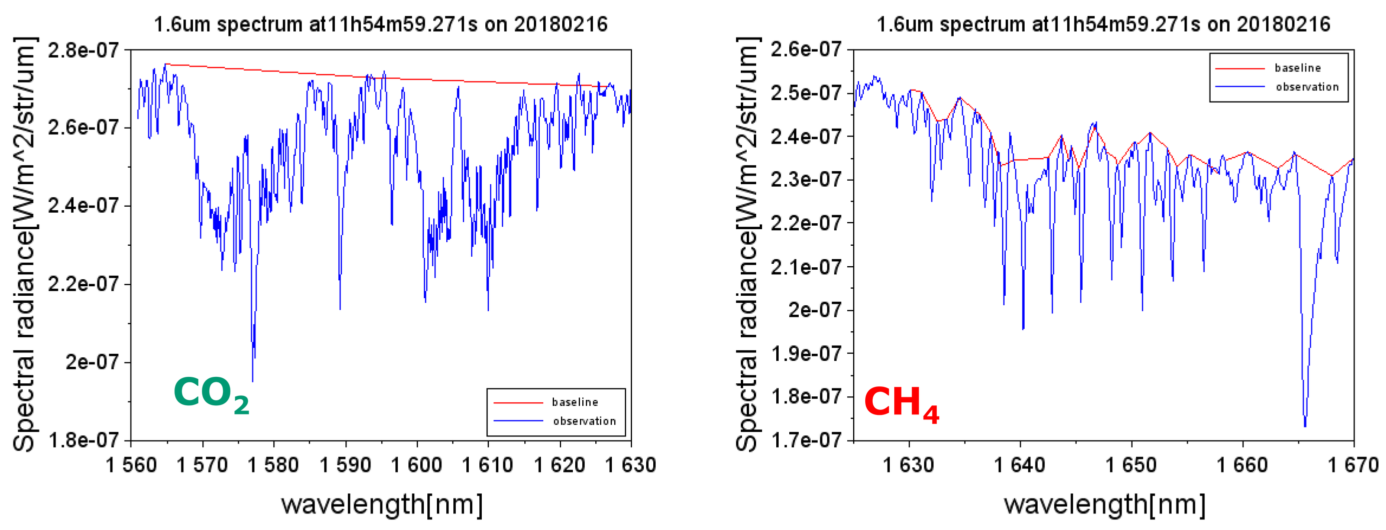
Normalized spectrum = (observed spectrum − baseline) / baseline

The Second point is to correct instrumental characteristics like wavelength position and width of instrumental function(ILS) by assuming the ILS as Gaussian as follows.

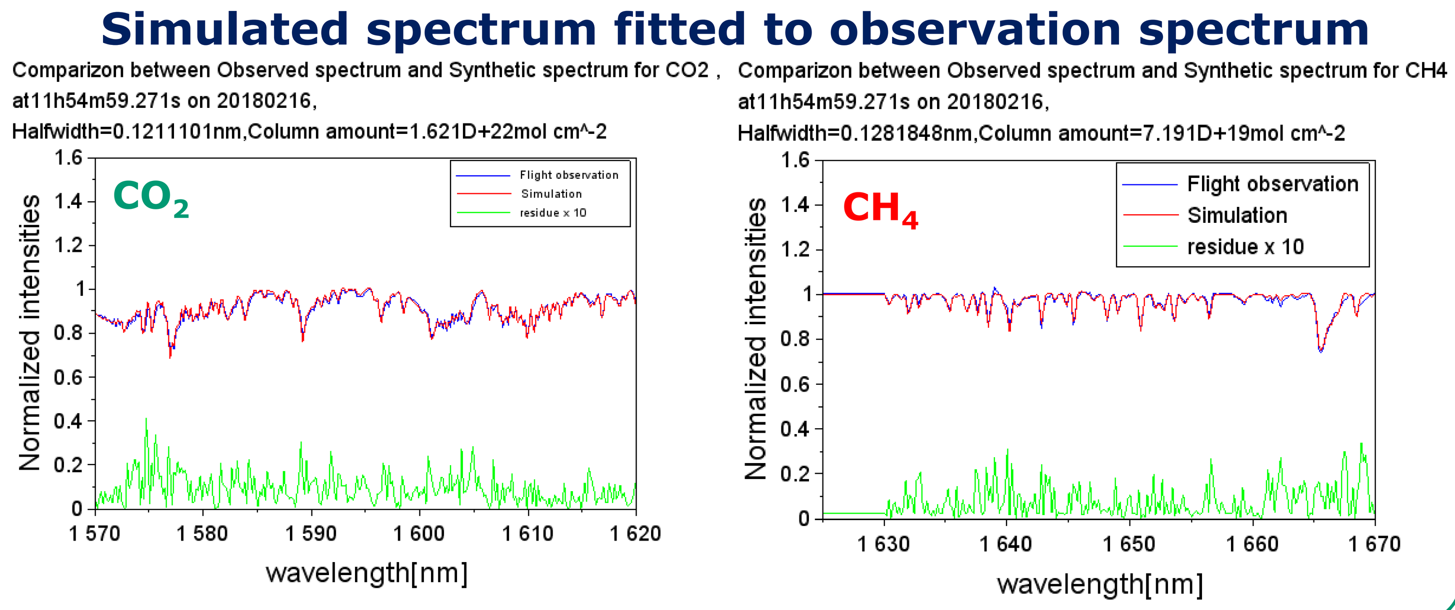
$$A\exp\left(-(\lambda-\lambda_0)^2/(2 \cdot w^2)\right)$$

During the flight on Feb.16, λ_0(center of wavelength) was shifted by around 0.1nm and w (half width) was narrower by around 60%, due to significant raise of the instrument temperature by 10℃.
In order to solve the problem, simulated spectrum was fitted to observed spectrum by optimization of target physical variables (column amount) as well as instrumental parameters (λ_0 , w).
Simulated spectrum was calculated from line intensities from HITRAN database took account of pressure broadening, then convolved by ILS. In advance of fitting process, both observation spectrum and simulated spectrum were normalized by baseline respectively.
As a result, simulated spectrum agreed with observation spectrum with residual of 1-2 % as well as estimated w (half width) around 0.12 nm (≒theoretical expectation of 0.12nm) .

Baseline estimation for observed spectrum



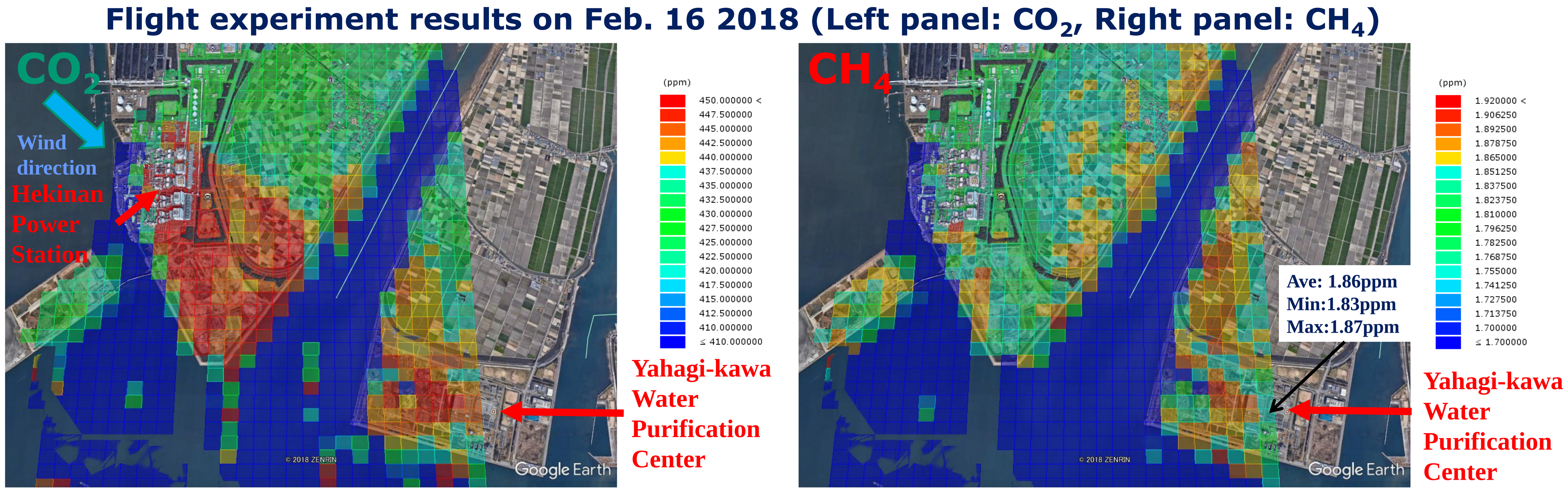
Simulated spectrum fitted to observation spectrum



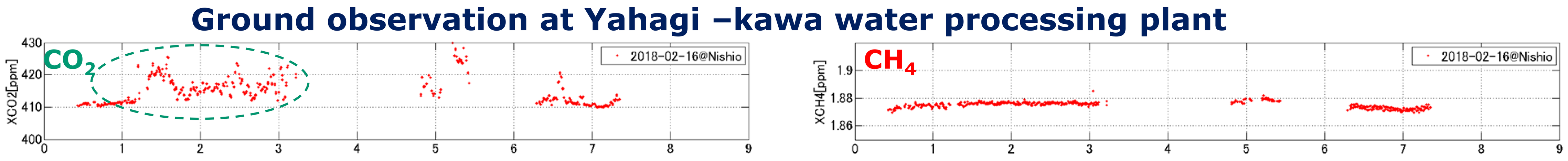
GHG column averaged density

The results of observing the Hekinan power plant (coal-fired power generation) over Aichi Prefecture are shown. At the Hekinan Power Station, high concentrations of CO_2 of 450 ppm or more are observed, and it can be seen that the high concentration area extends toward the downwind side. In the figure below, the results of ground-based observation of CO_2 at the downwind Yahagigawa Water Purification Center are shown. At the time of observation, the wind direction becomes northwesterly, and the CO_2 concentration is rising, supporting the results of aircraft observation.
As for CH_4 column averaged density, there were no significant enhancements around Hekinan Power Station. Some high concentrations were observed at the landfill site near the Yahagigawa Purification Center. In addition, the ground measurement result of CH_4 concentration in Yahagigawa Purification Center shows the result close to the airplane observation result (~ 1.86 ppm) in the vicinity by 1.88 ppm.

Flight experiment results on Feb. 16 2018 (Left panel: CO_2, Right panel: CH_4)



Ground observation at Yahagi –kawa water processing plant



Summary and future Work

As a measurement of greenhouse gases by aircraft, observation of high spatial resolution of several tens of meters was realized, and CO_2 and CH_4 emissions in urban areas were detected in facility units. The column averaged concentration was calculated quickly (about 10 seconds per spectrum) by an algorithm that simultaneously processes instrument correction and gas concentration calculation. In the future, we will further accelerate and realize real-time observation.