CH4-emission estimation from different sources using the present GOSAT and the next-generation imaging-spectrometer suites

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Abstract

The Thermal And Near infrared Sensor for carbon Observation Fourier-Transform Spectrometer (TANSO-FTS) onboard the Greenhouse gases Observing SATellite (GOSAT) was launched in Jan. 2009 to monitor global CO2 and CH4 distribution from space. The wide-spectral-range data by FTS can measure the partial-column density of the lower troposphere using sun-light reflected from the surface and thermal emission from the atmosphere. In addition to nominal global grid-observation, TANSO-FTS has an agile pointing system to target various CH4 point-sources as well as reference points every three days over years, and can capture the entire flux emitted vertically and horizontally from the source. We demonstrated the monitoring capability by using the natural-gas blowout event at Aliso Canyon, CA and tried to estimate the CH4 flux from a dairy farm in Chino, CA with the Weather Research and Forecasting model. The GOSAT footprint, which is much larger than the point-source area, reduces the enhancement of the retrieved column density close to the detection level. As the single-pixel data and acquisition time of 4 s by FTS limits the number of sampling points near the emission source, careful screening with wind speed and direction is required to acquire reference and source dataset for analysis. The largely fluctuated single data requires to be averaged to improve the precision, but the GOSAT data is spatially too sparse. We calculated the local CH4 flux from Chino using the correlation between wind speed and density, but the lack of a proper reference result in large errors. To solve the above-mentioned issues, we manufactured airborne imaging-spectrometer suites comprising two bands to measure CH4 and CO2 at 1.6 µm and O2 at 0.76 µm. They have 4,000 times more data than GOSAT, increase enhancement with higher spatial resolution, and select proper upwind reference with imaging capability. In Feb. 2018, we flew over greater Nagoya with the mixture of possible emission sources such as energy production, waste water, dairy farm, and agriculture. The spectral image of spatial resolution <100 m has clearly detected enhancement from individual local sources of CH4 and CO2. We add one more spectrometer to measure short-lived NO2 to detect plume orientation. Our goal is to individually estimate city-level CH4 flux from different source sectors.

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Rising Atmospheric Methane

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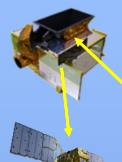
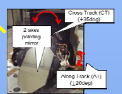
The Thermal And Near infrared Sensor for carbon Observation Fourier-Transform Spectrometer (TANSO-FTS) onboard the Greenhouse gases Observing SATellite (GOSAT) was launched in January 2009 to monitor global CO_2 and CH_4 distribution from space. The wide-spectral-range data of FTS can measure the partial-column density of the lower troposphere by simultaneously using sun light reflected from the Earth's surface and thermal emission from the Earth's atmosphere. In addition to nominal global grid-observation, TANSO-FTS has an agile pointing system to target various CH_4 point-sources as well as reference points every three days, and can capture the entire flux emitted vertically and horizontally from the source. We demonstrated the monitoring capability by using the natural gas blowout data in 2015 at Aliso Canyon, CA and tried to estimate the CH_4 flux from the point source using the dairy-farm-area dataset in Chino, CA with the Weather Research and Forecasting (WRF) model. Large footprint and sparse sampling result in large flux estimation error. Our goal is to identify the emission source and individually estimate CH_4 flux from different source sectors by imaging spectrometer suites with higher spatial resolution. In February 2018, we flew the airborne instruments over the third largest city Nagoya, Japan.

Using the present GOSAT

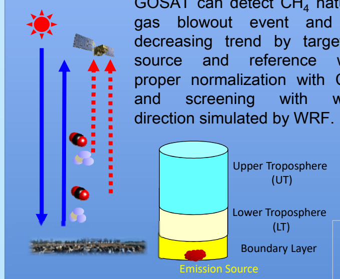
(1) Remote sensing from platforms above the atmospheric boundary layer can capture total emissions using the solar reflected light passing from the top of the atmosphere to the Earth's surface.
(2) Anthropogenic emission area of CH_4 is generally smaller than CO_2 and type of source can be categorized but emission amount has large uncertainty.



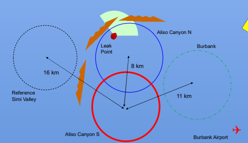
TANSO-FTS onboard GOSAT with an agile pointing system

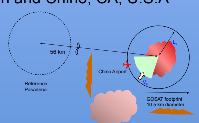


GOSAT can detect CH_4 natural gas blowout event and its decreasing trend by targeting source and reference with proper normalization with CO_2 and screening with wind direction simulated by WRF.



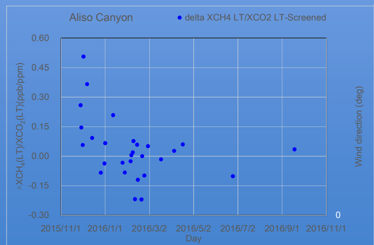
	Aliso Canyon (AC) CH$_4$ blowout trend monitoring	Southern California flux estimation
Footprint center location	AC N (34.28° N, 118.53° W) AC S (34.21° N, 118.54° W) Burbank (34.26°N, 118.44°W)	Chino (34.00° N, 117.58° W)
Reference	Simi Valley (34.28° N, 118.69° W)	Pasadena (34.12 ° N, 118.15° W)
Enhancement from background	Large enough but decrease with time	Close to detection limit Assumed to be constant
CO_2 emission source inside IFOV	Lower	High
Source location	Near edge	Widely spread within the footprint
Wind direction	Unstable	Mostly from west

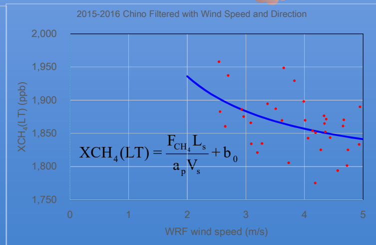




Aliso Canyon and Chino, CA, U.S.A

GOSAT measures both solar reflected light from the Earth's surface (SWIR) and thermal emission from the Earth's atmosphere (TIR) providing CO_2 partial-column densities of UT and LT.

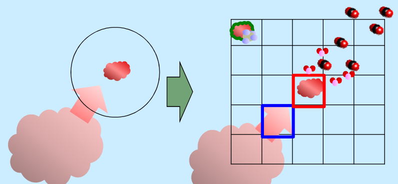


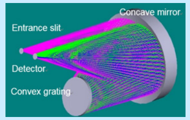


$$XCH_4(LT) = \frac{F_{CH_4} L_s}{a_p V_s} + b_0$$

Single satellite-measured data are largely fluctuated. Flux from Southern California can be estimated from fitting parameter of inverse correlation between enhancement of the partial column density of the lower troposphere and wind speed from accumulated a-year long data.

The next-generation imaging-spectrometer suites





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

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 sector

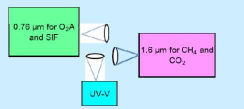
Item	O_2 A and SIF	CO_2 and CH_4
Spectral coverage	747–783 nm	1.56–1.67 μm
Spectral resolution	0.9 Å	2 Å
Detector	Si	InGaAs cooled at +10℃ by thermoelectric cooler
Pixel number and size	2048 by 2048 pixels, 6.5 μm by 6.5 μm	640 (spectra) by 512 pixels (cross track) 20 μm by 20 μm
Integration time	0.5 sec (typical)	0.5 sec (typical)
Spectral Binning	6 pixels	2 pixels

Uncertainty of wind speed and direction and lack of proper reference cause errors in flux estimation. Imaging capability with higher spatial resolution are needed.

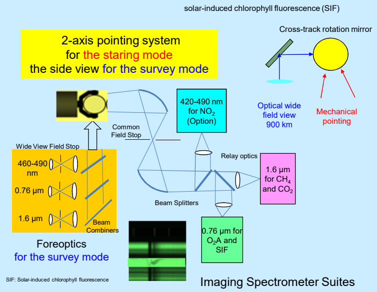
$$F_{CH_4} = a_p \frac{\Delta XCH_4(LT) \times V_s}{L_s}$$

$$\Delta XCH_4(LT) = XCH_4(LT)_s - XCH_4(LT)_r$$

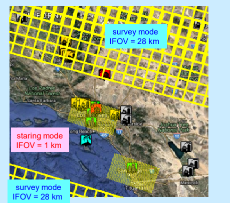
We propose an imaging spectrometer suite to measure CO_2, CH_4, and NO_2 with a Å spectral resolution to estimate flux from different source sectors.



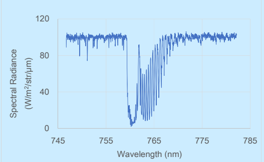
Feb. 2018 Configuration

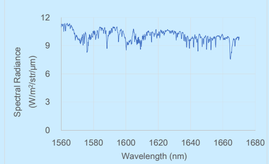


Imaging Spectrometer Suites

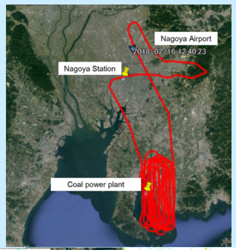


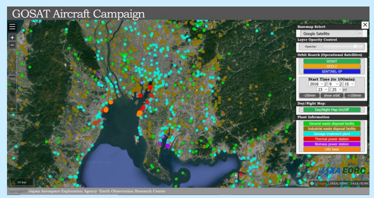
Survey entire earth's surface
Selecting Proper reference
Staring
- 1 km resolution will enhance dCH_4
- Image can detect plume and has closer reference

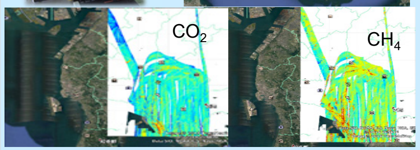




Measured absorption spectra of O_2, (upper) CH_4, CO_2. (lower) by airborne observation on Feb. 16, 2018

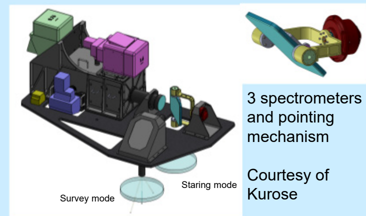






Demonstration flight over greater Nagoya in February 2018. Large CO_2 emission sources, including a coal power plant and the transportation sector, and possible CH_4 sources from agriculture, energy manufacturing, and waste that are geographically mixed.

Different GHG source location of greater Nagoya
CO_2: Poser plant, traffic, industry
CH_4: Waste water, liver stock, Gas production



3 spectrometers and pointing mechanism

Courtesy of Kurose

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