XCO_2 observation above power plants from Japanese hyperspectral sensor, HISUI

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ABSTRACT

The aim of this work is to study the possibility of CO_2 column-averaged mole fractions (XCO_2) derivation from hyperspectral data acquired by Hyperspectral Imager SUIte (HISUI) which has been borne on the International Space Station (ISS) since 2019. To derive XCO_2 from medium spectral resolution (12.5 [nm]) like HISUI, we newly developed XCO_2 retrieval algorithms based on MODTRAN which can retrieve ILS width, H_2O column amounts, and XCO_2 simultaneously. The algorithm was adopted to HISUI hyperspectral data acquired in that area which involved a coal-fired plant as a local emission source located on the east coast of Japan. HISUI observed the area by 2 times in 2021, and prominent enhancement of XCO_2 of 468.8 [ppm] on April 9 and 485.6 [ppm] on August 10 were found exactly above the stack. The plume shape was found to be agreed with the wind direction at the time of the day thanks to its high spatial resolution of ~ 20 [m]. Assuming a Gaussian plume profile for the XCO_2 distribution, the CO_2 emission rate was estimated. The results were 86.5 [kg/s] and 177.2 [kg/s] for the case of April 9 and August 10 respectively exactly above the stack. Thus, the present research has paved the way for direct estimation from space of CO_2 emissions rate at power plants.

METHOD

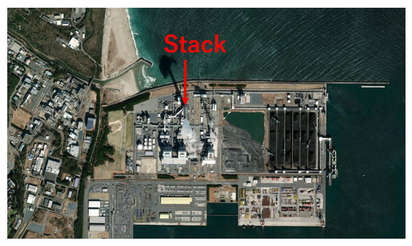
Typical SWIR spectrum acquired by HISUI

H_2O band around 1120nm with simulation spectra

CO_2 band around 2050nm with simulation spectra

The same as the left panel but enlargement

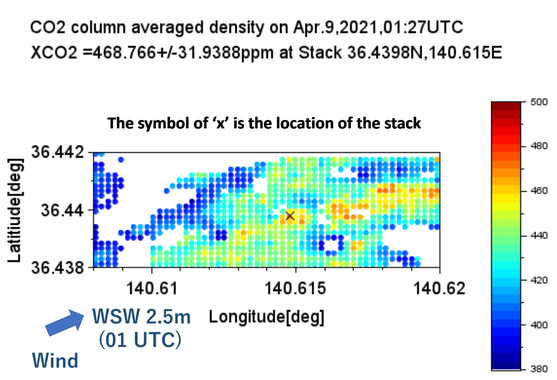
RETRIEVAL of XCO_2 at POWER PLANT



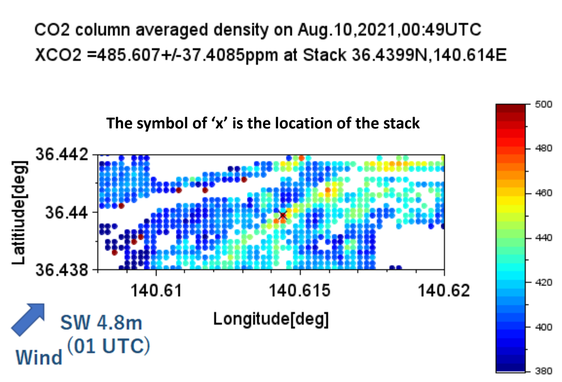
Target: Power plant on the east coast of JAPAN (36.436°N, 140.614 ° E)

Retrieved results	Apr. 9, 2021	Aug. 10, 2021
H_2O area mean	0.907 [g/m^2]	5.06 [g/m^2]
ILS FWHM	12.0 [nm]	15.0 [nm]
XCO_2 area mean	423.1 [ppm]	410.6 [ppm]
XCO_2 @stack	468.8+/-31.9 [ppm]	485.6+/-37.4 [ppm]
(XCO_2 monthly average by JMA)	424.3 [ppm]	410.3 [ppm]
	@Ryori (39.03°N, 141.82°E)	

Apr. 9, 2021



Aug. 10, 2021



CO_2 Emission rate estimation

Gaussian plume approximation

$$X_{CO2} = \Delta X_{CO2} \cdot e^{-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2} - X_{CO2\_BG}$$

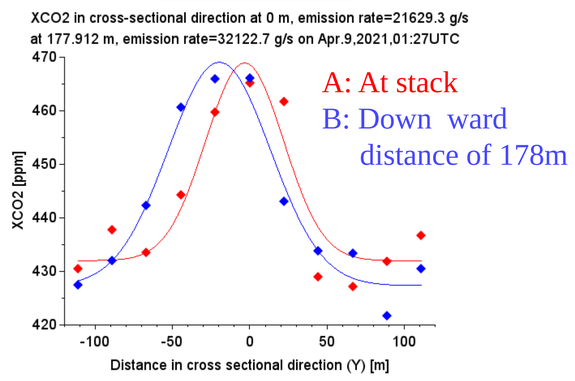
Enhance-ment | Gaussian plume | Back-ground

Emission rate estimation

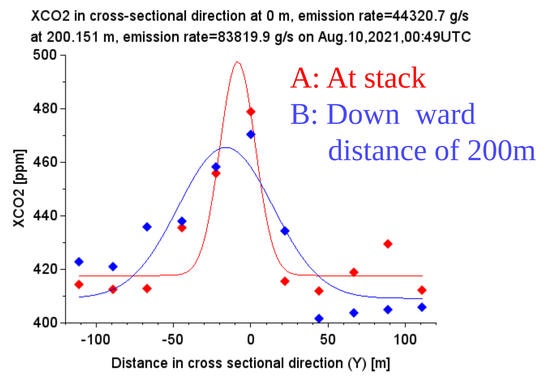
$$F = \Delta X_{CO2} \cdot m_{CO2} \int_{z_0}^{z_{max}} n_{dry} dz \cdot \sqrt{2\pi} \cdot \sigma_y(x) \cdot u \quad [g\ s^{-1}]$$

Enhance-ment | Air mass | Plume cross section | Wind velocity

Apr. 9, 2021



Aug. 10, 2021



Physical quantity	Sym-bol	Unit	Apr. 9, 2021	Aug. 10, 2021
Enhancement	ΔXCO_2	ppm	A: 36.9 B: 41.7	A: 80.0 B: 56.4
Plume cross-sectional spread	σy	m	A: 25.2 B: 33.1	A: 11.4 B: 30.6
Wind velocity (at Mito-city)	u	m s^{-1}	2.3	4.8
Emission rate (by HISUI)	F_H	kg s^{-1}	A: 86.5 B: 128.5	A: 177.2 B: 335.3
Emission rate (bottom up)	F_b	kg s^{-1}	188.9*	

*Power plant capacity =2 × 10^6 kW [ref.3] , assumed conversion factor=0.34 kg/kw/h

Reference

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