A concept of mini-satellite for air quality observation

- a possibility after the GEMS satellite-

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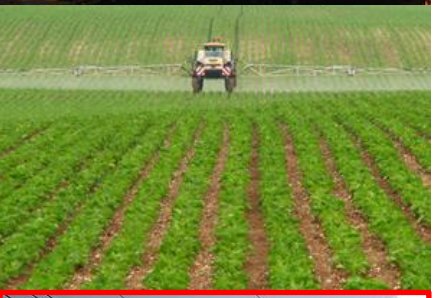
Contents

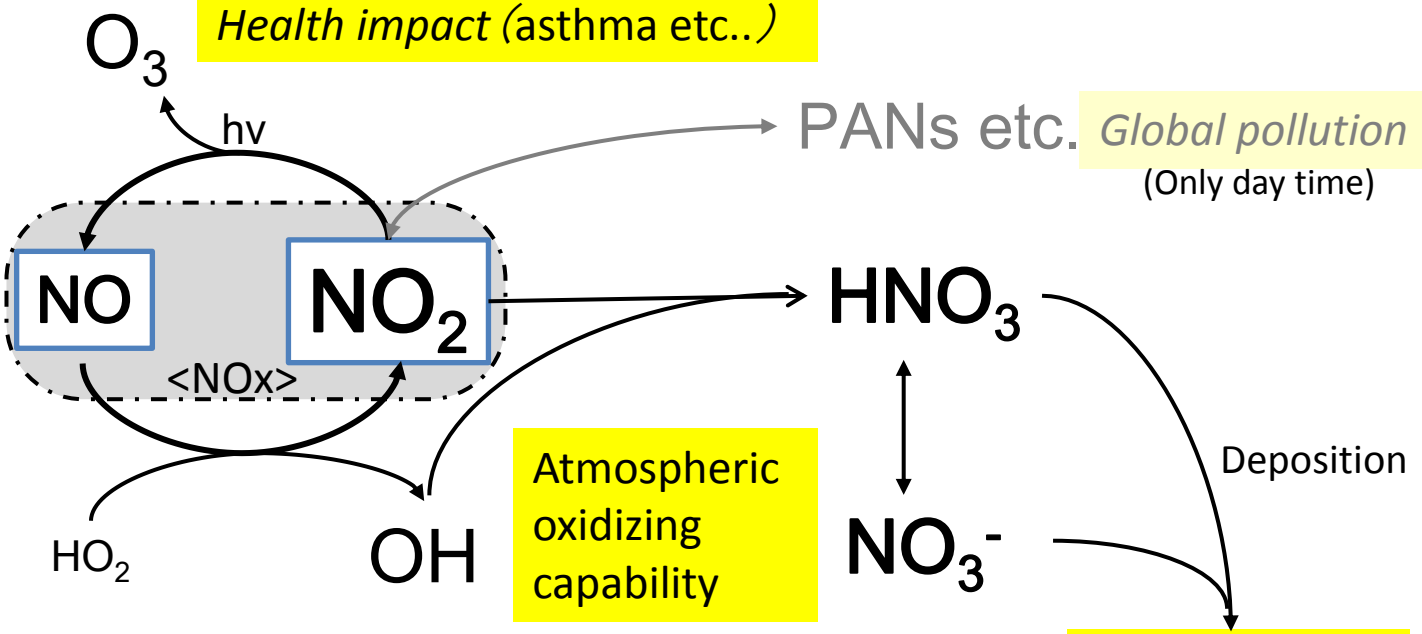
NOx chemistry – impact on human health and environment

natural



Anthropogenic

Photochemical smog :
Health impact (asthma etc..)



●WHO reported that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure.

●”High spatial resolution”, such as 1x1km, observation is required to understand the inventory of NO_2 even from minor narrow sources.

Mission Concept

Mission concept: A microsatellite with high horizontal resolution

Scientific requirement

Products	**Standard: NO_2,O_4**
Detection limit （**NO_2 total column density**）[molecules/cm^2]	**3.0×10^{15} (5%)** （about 0.6ppb in boundary layer）
（ex）Tropospheric NO_2 column amount [molecules/cm^2]	6.0×10^{16} (Boundary layer 4.7×10^{16})
IFOV	1 km x 1km (2 km x 2 km)
Vertical resolution	Tropospheric column
Swath width	approx. 200 km

In this study, we performed a feasibility study for observation precisions of NO_2

→Synthetic spectra are calculated using SCIATRAN (RTM) with two geometries.

→Slant column densities (SCDs) are derived by DOAS method and converted to vertical column densities (VCDs) by division with air mass factor (AMF) derived from SCIATRAN.

Instrumental parameters in this study

These parameters made with A. Kuze (JAXA)

Setup of each parameter

Parameters	The number of parameters	Elements of parameters
Wavelength range	2	Reference : 425 -450 nm(conventional region) 460-490 nm
Area	2	Seoul (as polluted area) Hokkaido (as clean area)
Season	1	Winter(Jan.)
Altitude of satellite	1	300 km
Spectral resolution (FWHM)	1	0.4 nm
Sampling step	1	0.1 nm
Detector size	1	0.064 mm
Aperture size	1	0.74 cm
Read noise	1	10 e
IFOV	2	1 x 1 km^2 2 x 2 km^2

Data processing method

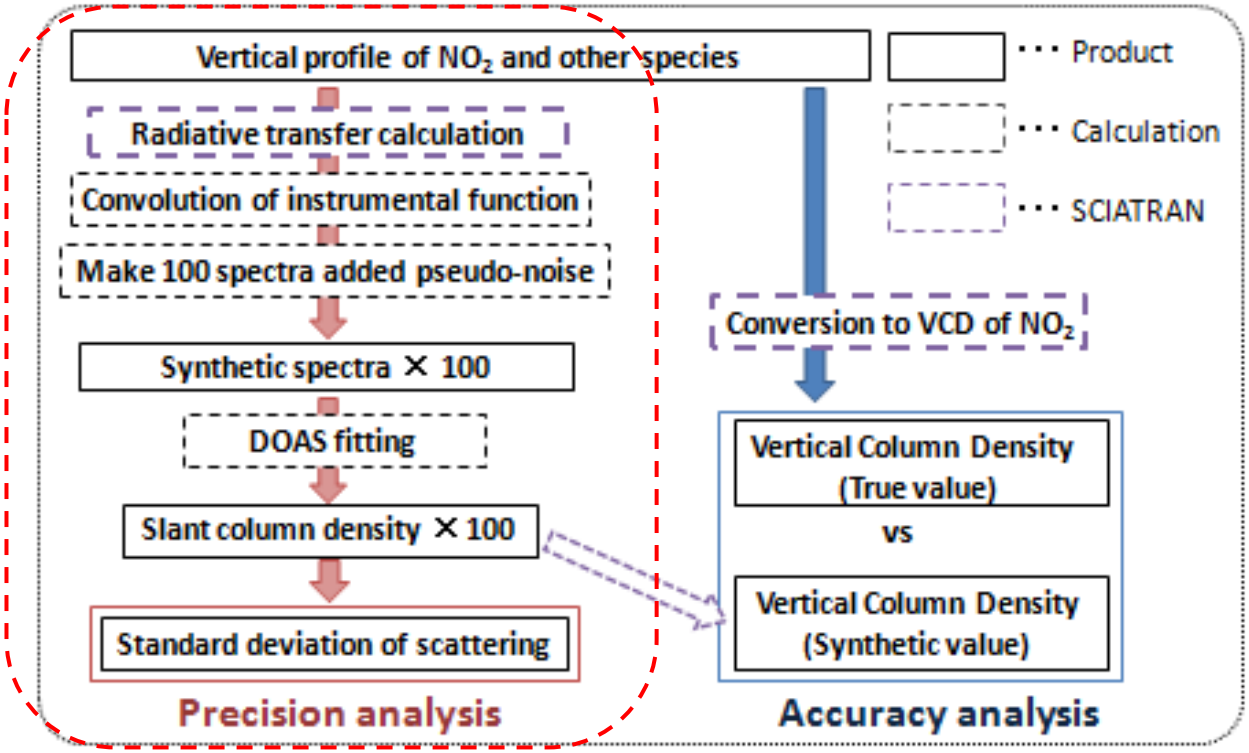


Fig. Flow of algorithm for estimation of precisions and accuracies of retrieved NO_2 (*Noguchi et al.*, 2011)

Precision analysis :

- Prepare the vertical profile of NO_2 and the other species as input data into RTM (SCIATRAN)
- Convolute with Gaussian slit function and make 100 spectra added the pseudo-noise
- Conduct DOAS fitting and retrieve SCDs from each spectrum
- Estimate precisions of retrieval NO_2 column as 1σ standard deviation of 100 SCDs.

Input profile data - area selection

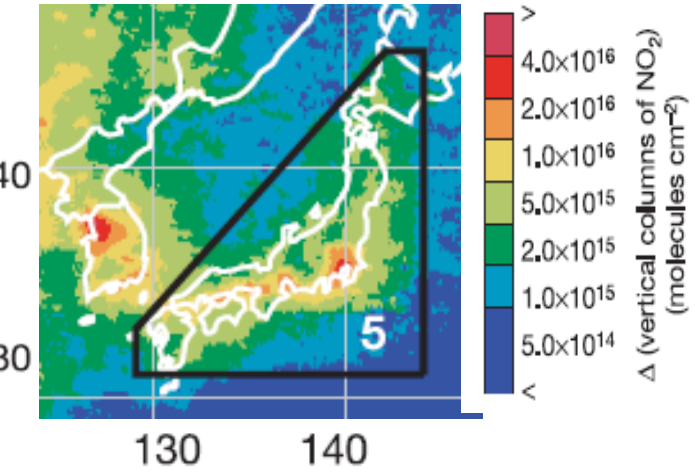
Area

- **Seoul (37.3 N, 127.0 E)**

→ **as polluted region**

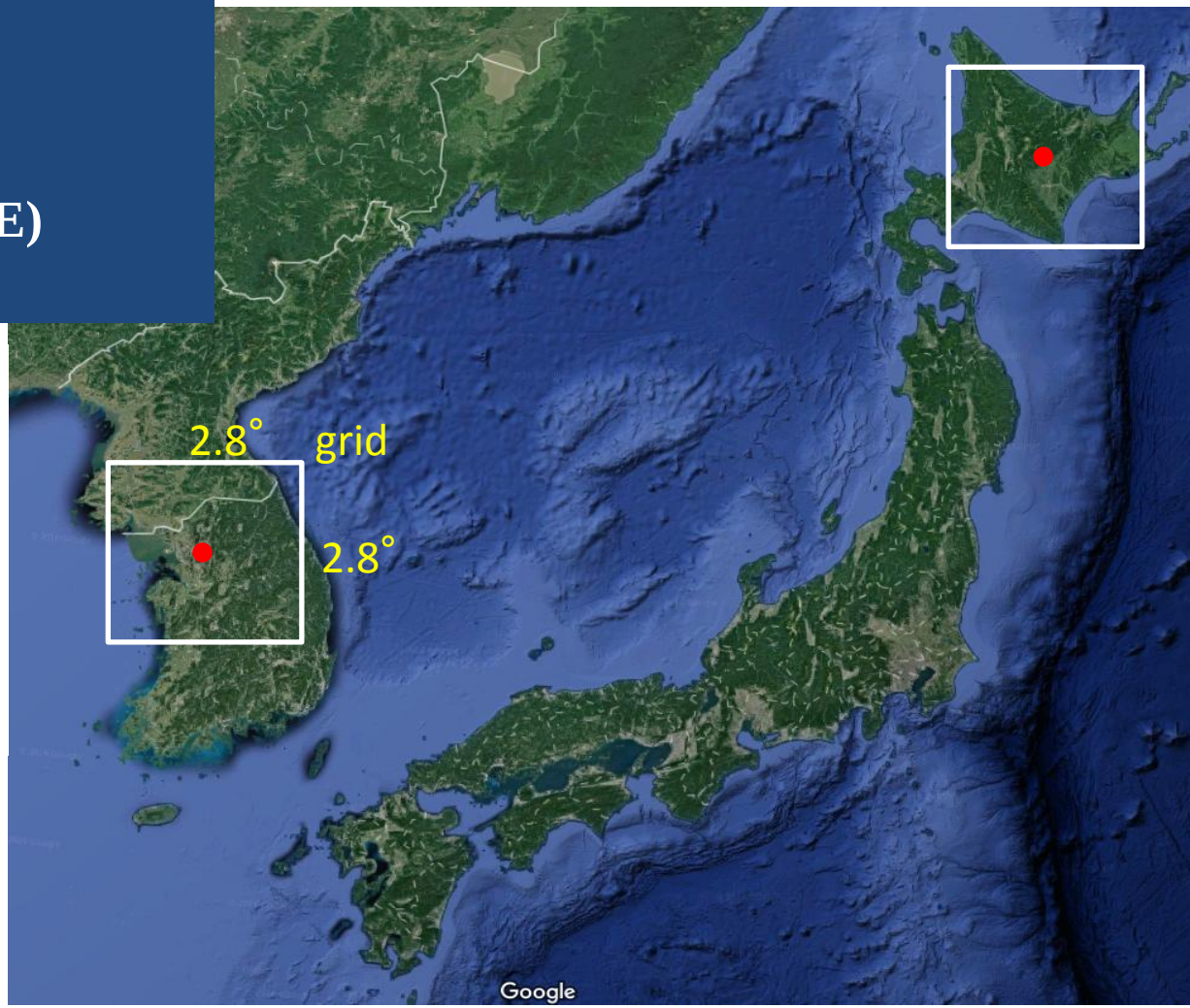
- **Hokkaido (43.3 N, 143.3 E)**

→ **as clean region**



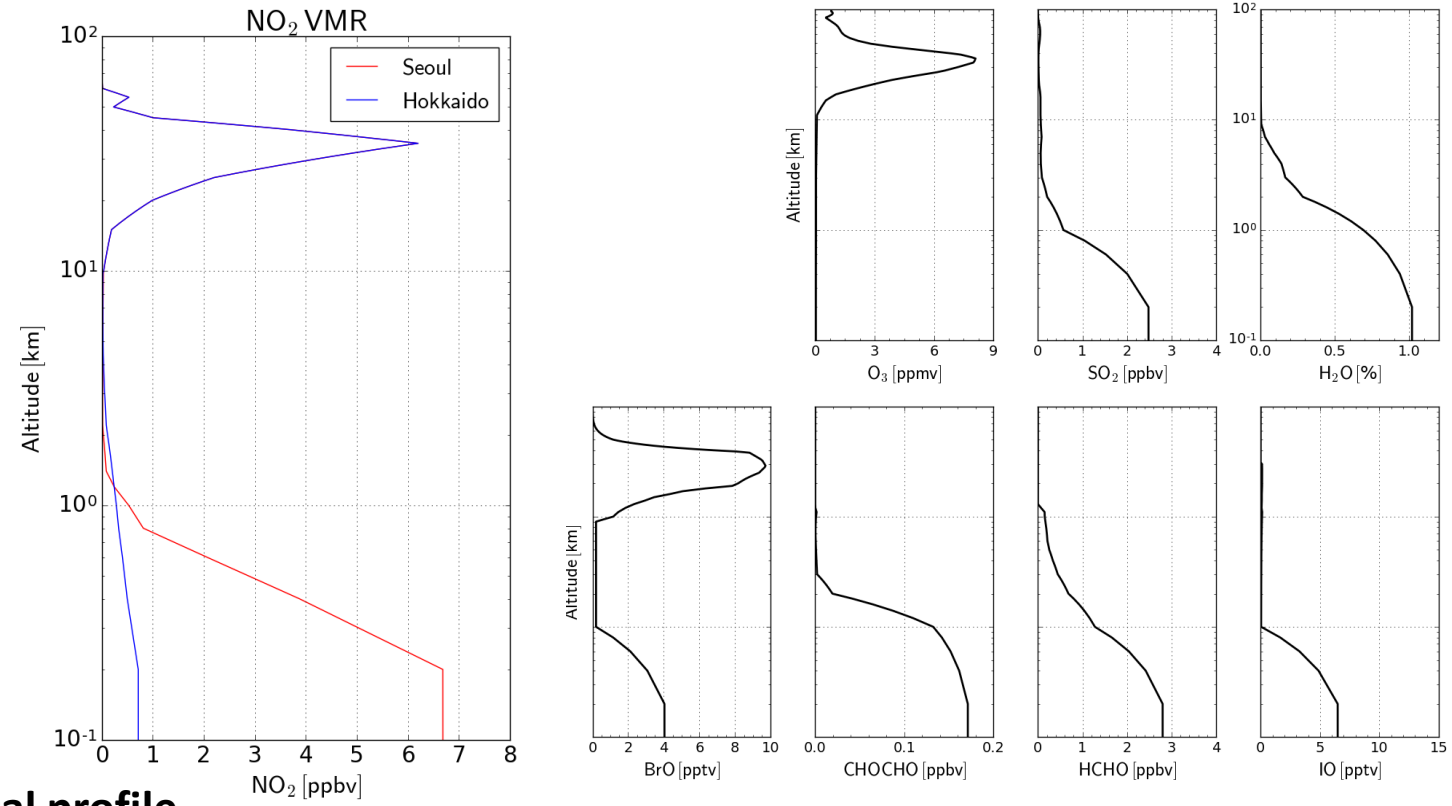
SCIAMACHY tropospheric NO2 vertical columns averaged between December 2003 and November 2004

A. Richter et al., (2005) *nature*



Google earth

Input profile data - preparation of vertical profile



NO_2 vertical profile

Troposphere : surface – 10 km CHASER model, monthly mean, Jan. 2005 (2.8 ×2.8° gridded cell)

Stratosphere : 10 km – 100 km SOCRATES model , annually mean (from *Aeronomy of the middle atmosphere ver.2* by *G.P. Brasseur and S. Solomon*)

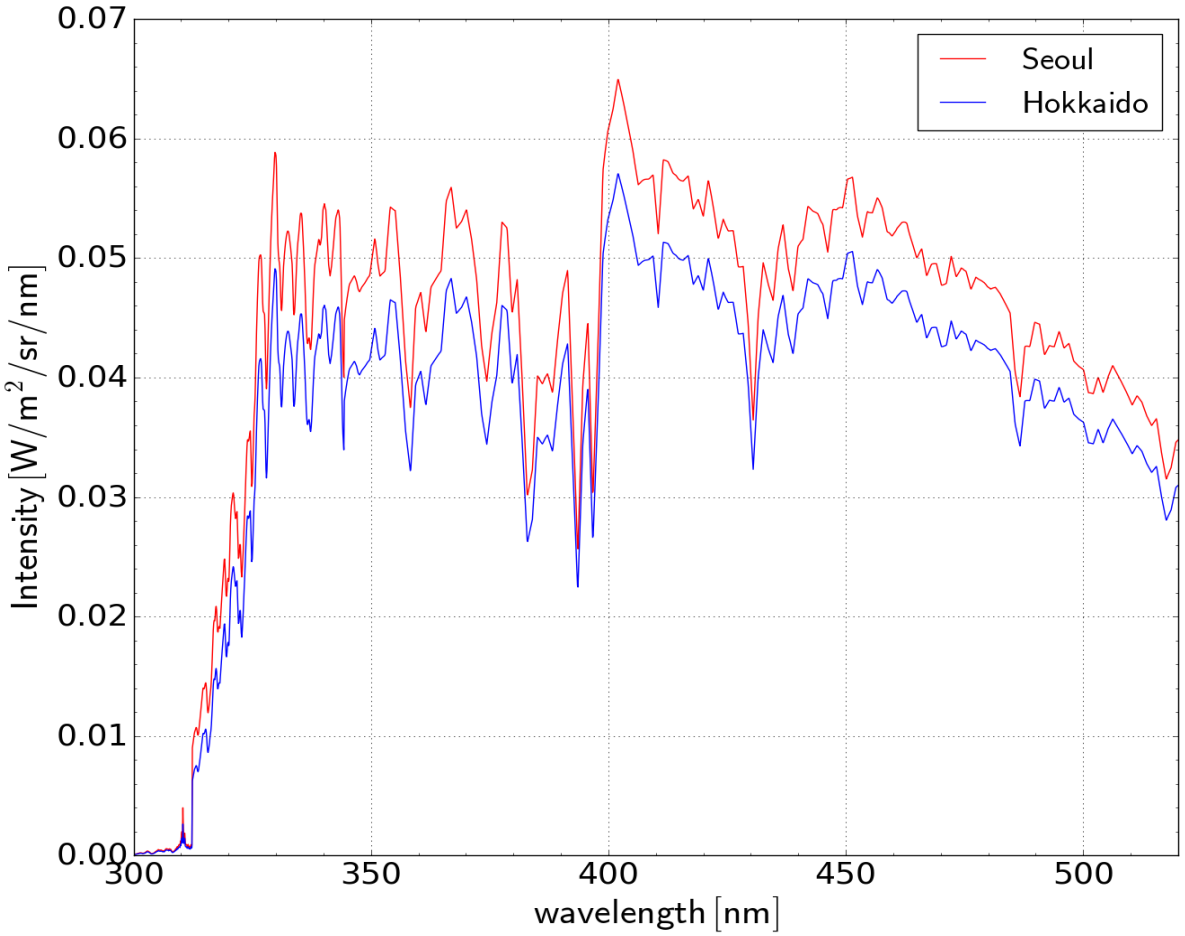
Other gases

Provided by GMAP-Asia science team (*Noguchi et al.*, 2011)

Pressure, Temperature

U.S. standard atmosphere

Results - Synthetic spectra from SCIATRAN



・This figure shows a example of radiance spectra at 300 km of altitude by SCIATRAN.

・Spectra convolved with Gaussian slit function with an FWHM of 0.4 nm were plotted in steps of 0.1 nm.

・The radiance at Seoul was larger than that at Hokkaido because SZA assumed at Seoul in this simulation was lower than that at Hokkaido.

Results – Expected SNRs for each IFOV case

SNRs expected in each wavelength and spatial resolution

Wavelength [nm]	Spatial resolution [km^2]	Expected SNR (Electronics)	Expected SNR (Shot)	Dark current SNR	Expected SNR (all)
480 (460 - 490)	**1x1**	1642	691	2806	**621**
	2x2	9287	1954	11222	**1885**
450 (425 - 450)	**1x1**	1411	620	2518	**554**
	2x2	7983	1753	10073	**1688**

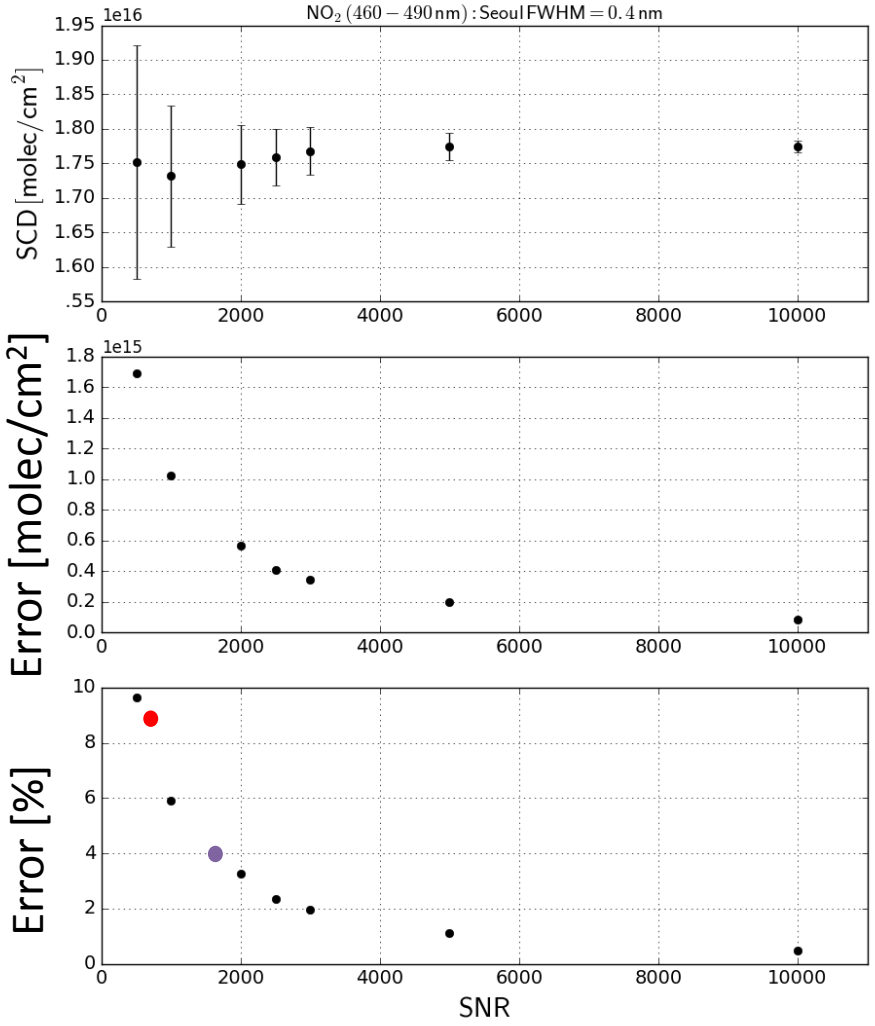
・We assumed that the detector was Si-CMOS 2D array sensor and the optical efficiency and quantum efficiency was 0.43.

・In both cases of wavelength, expected SNRs of 2 x 2 km^2 became about three times larger than them of 1 x 1 km^2.

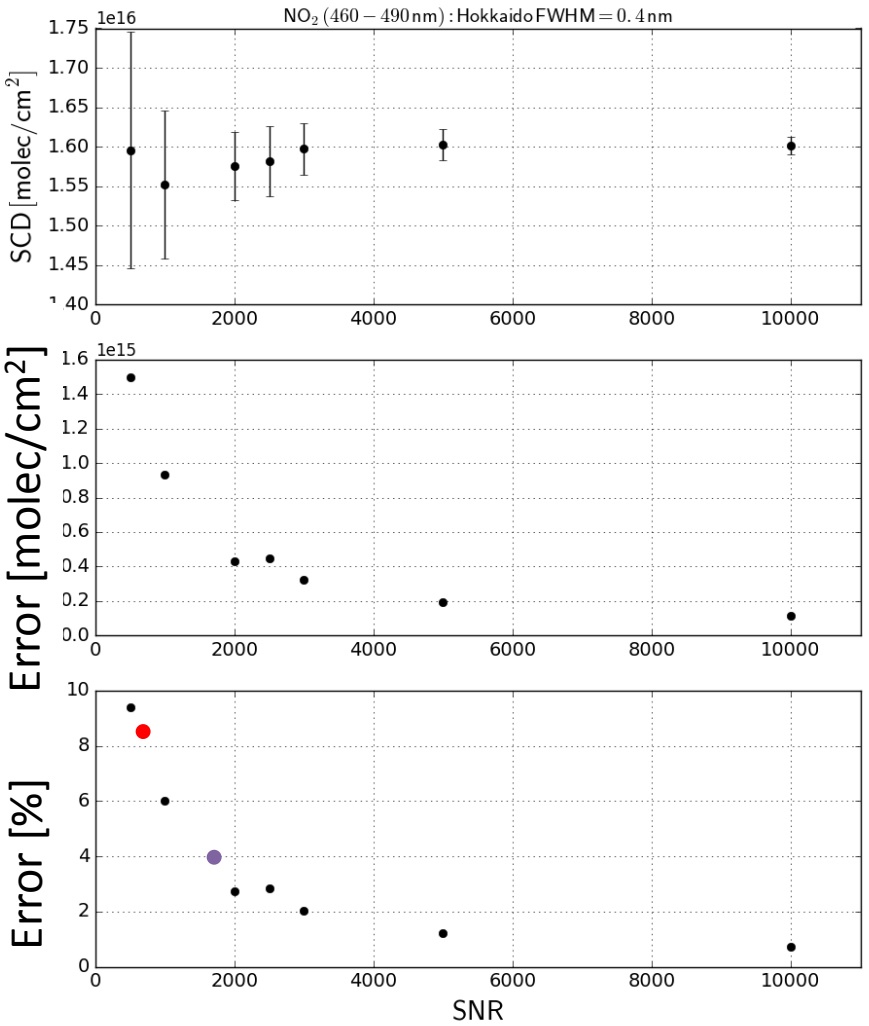
Results and discussion

Winter (Jan.), Alt. of satellite = 300 km, FWHM = 0.4, 460-490 nm, Δλ =0.1 nm

Left : Seoul



Right : Hokkaido



1x1 km^2 → SNR=621 @ 480 nm (red), 2x2 km^2 → SNR=1885 @ 480 nm (purple)

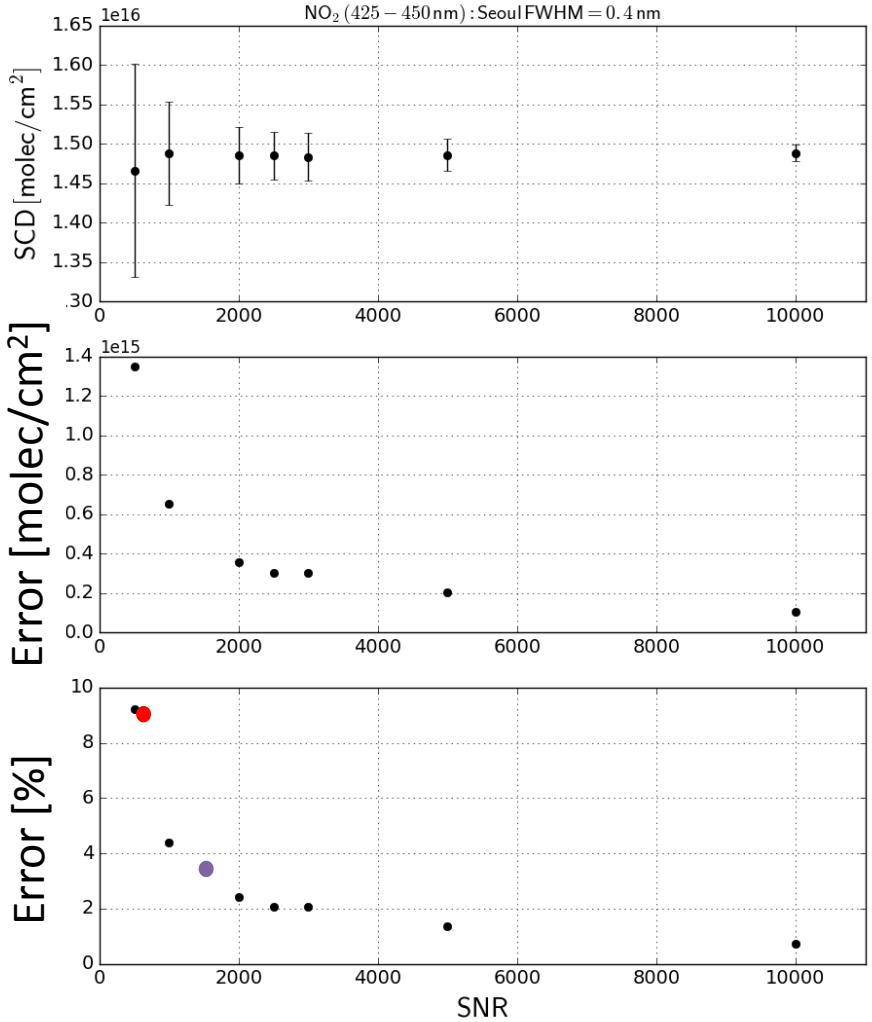
Upper figure : SCD (total = tropo. + strato.), Middle figure : Error [molec/cm^2], Lower figure : Error [%]

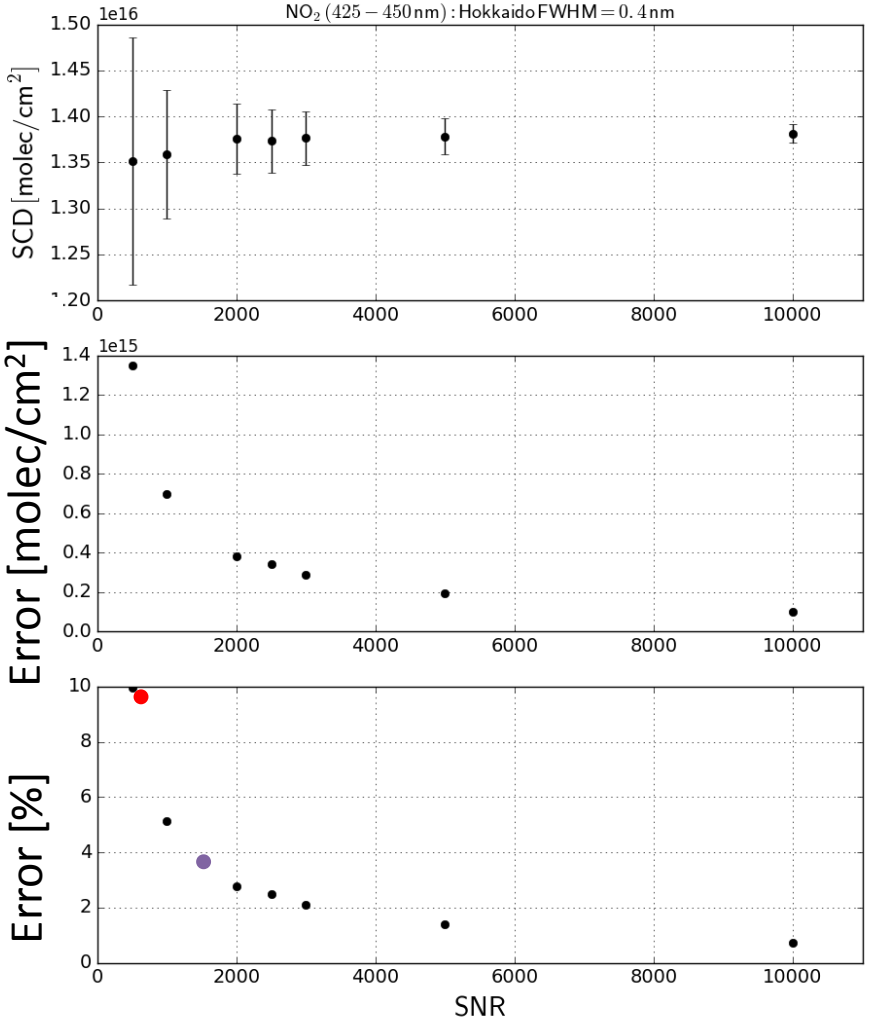
Results and discussion

Winter (Jan.), Alt. of satellite = 300 km, FWHM = 0.4, 425-450 nm, Δλ =0.1 nm

Left : Seoul

Right : Hokkaido





1x1 km² → SNR=554 @ 450 nm (red), 2x2 km² → SNR=1688 @ 450 nm (purple)

Upper figure : SCD (total = tropo. + strato.), Middle figure : Error [molec/cm²], Lower figure : Error [%]

Summary

- **There is no differences of precisions between two different wavelength, 425 – 450 nm and 460 – 490 nm.**

→ The precisions are independent from wavelength used in DOAS in this simulation.

- **Scientific requirement of the precision of total NO2 column was about 5%**
- **Spatial resolution of 1x1 km^2 provided SNR about 500 and the measurement precision to be 9% in this simulation.**
- **Spatial resolution of 2x2 km^2 provided SNR about 1700, and the measurement precision to be 4%.**

→ 1x1 km^2-resoluted observation did not satisfy the scientific requirement in current instrumental concept although 2x2 km^2 entire satisfied.

→Next step

- lower orbit
- changing the detectors
- more broader frequency resolution

Thank you very much.