A feasibility study for the monitoring of diurnal variations of tropospheric NO_2 over Tokyo from a geostationary satellite

Katsuyuki Noguchi (1,2), Andreas Richter (1), Andreas Hilboll (1), John P. Burrows (1), Hitoshi Irie (3), Sachiko Hayashida (2), and Yu Morino (4)

(1) Institute of Environmental Physics, University of Bremen, Bremen, Germany, (2) NaraWomen's University, Nara, Japan, (3) Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, (4) National Institute for Environmental Studies, Tsukuba, Japan

Universität Bremen

国立大学法人 奈良女子大学
Nara Women's University

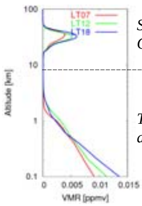
Abstract

We have conducted a feasibility study for the monitoring of diurnal variations of anthropogenic nitrogen dioxide (NO_2) in the lower troposphere over Tokyo, Japan, assuming a geostationary satellite's measurement. The retrieval simulation showed that the total NO_2 slant column (SC) density (2.5-4.5×10^{16} cm^{-2}, depending on local time and season) could be measured with a precision of 10-20% at signal-to-noise ratio (SNR)=200 and 1-2% at SNR=2000, respectively. In our estimation, the precision of the SC did not strongly depend on local time (LT5-18 in summer and LT7-16 in winter) or season (summer and winter). We found that the diurnal variation of total NO_2 SC density from morning to evening (the magnitude is about 1.0×10^{16} cm^{-2}) could be well detected by a sensor with SNR>500. The detection of a local minimum appearing at summer noon (0.5×10^{16} cm^{-2}) needs better precision (SNR>1000).

Method

Calculating radiance

- SCIATRAN v2.2.2
- Tokyo(36ºN, 140ºE)
- Diurnal variation of NO_2 (strat. & trop.)
- Summer & winter
- Aerosols



Stratosphere: Bremen 3-D global CTM (based on SLIMCAT)

Troposphere: CMAQ for Tokyo area

Figure 1: Simulated diurnal variations of NO_2 for stratosphere and troposphere.

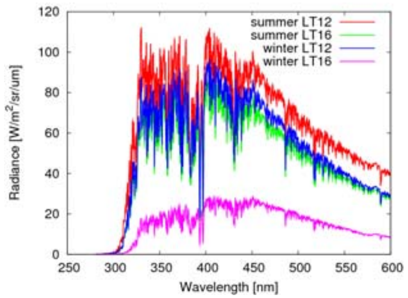


Figure 2: Earth's atmospheric radiance at satellite calculated by SCIATRAN for summer and winter at LT12 and 16

Adding noise to radiance

Noise scenario (two types)
1. Constant SNR (200,500,100,2000)
2. CCD sensor (5km×5km, 1hr), which is currently discussed for Japanese geostationary instrument

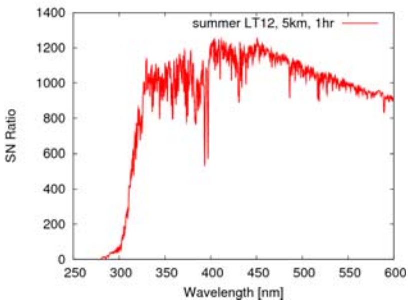


Figure 3: Example of Signal-to-Noise ratio calculated by using the CCD sensor specification with a spatial resolution of 5km and a time resolution of 1hr, which is currently discussed for a Japanese geostationary instrument. Shot noise is assumed to be the main component of noise.

DOAS fitting

Fitting window at 425-450nm, including O_3, NO_2, H_2O, CHOCHO, and O_4

Slant column (SC)

Results – Precision and Bias of Slant Column Retrievals

Diurnal variation of SC

- Diurnal variation of SC: ~10^{16} [cm^{-2}], detectable with SNR>500
- Local minimum in summer afternoon: 0.5×10^{16} [cm^{-2}], detectable with SNR>1000
- SC (i.e., air mass factor) depends significantly on wavelength in the fitting window (425-450nm)

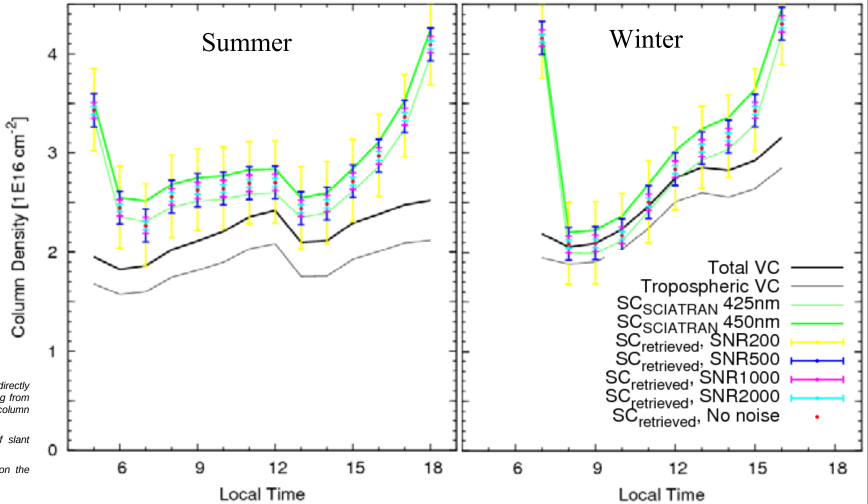
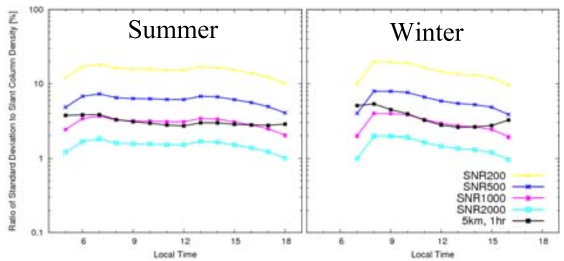


Figure 4 (top): Diurnal variations of slant column densities directly calculated by SCIATRAN in green and retrieved by the DOAS fitting from the spectra (points with error bars). Tropospheric and total vertical column densities are also shown in black and gray.

Figure 5 (Bottom, left): Diurnal variations of relative precision of slant column densities by the DOAS fitting.

Figure 6 (Bottom, right): Dependency of slant column densities on the temperature of absorption cross-section in the DOAS fitting.

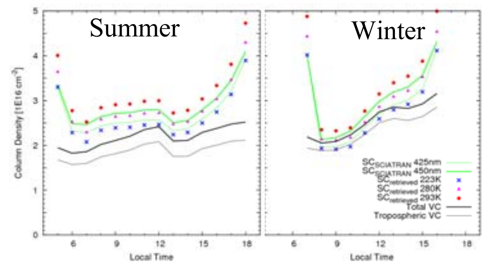
Relative precision of SC retrieval



- Precision of total SC is 10-20% for SNR200 and 1-2% for SNR2000.
- Precision of SC has small dependency on local time and season.
- CCD sensor currently discussed has a precision of 2-4% (~SNR1000).

Bias caused by temperature dependence of cross-section

Temperature dependence of absorption cross-section (σ) has been introduced into the RTM.



- Use of σ at 223K or 293K causes a bias of 0.2-0.3×10^{16} [cm^{-2}].
- σ at lower temperature (223K) gives a better fitting results in morning and evening due to larger light path in the stratosphere

Future work…

- Because the solar zenith angle (SZA) varies strongly in geostationary observations, the dependency of surface albedo on SZA should be considered. To correct for this, a Bidirectional Reflectance Distribution Function (BRDF) will be implemented into the simulation.
- Separation of the tropospheric SC from the total SC and air mass factor calculation should be examined for realistic scenario.

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