Comparison of tropospheric NO_2 observations by GOME and ground stations over Tokyo, Japan

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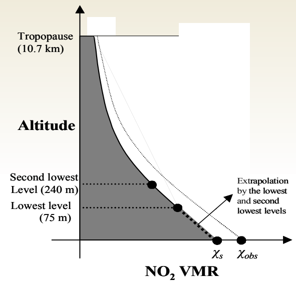
We compared Global Ozone Monitoring Experiment (GOME) and ground-based observations of tropospheric NO_2 to test whether satellite observations could successfully detect the behavior of tropospheric NO_2. In the comparison, the surface NO_2 VMR was scaled to the tropospheric VCD using vertical NO_2 VMR profiles, which were calculated using the chemical transport model CMAQ/REAS. We found that the GOME observations represent the behavior of NO_2 more closely at the relatively clean stations than at the highly polluted stations. This tendency was thought to result from the horizontal heterogeneity within a GOME footprint. The pollution in Tokyo is so spatially concentrated that the rural regions contaminating GOME pixels could also reduce the observed NO_2 concentration from its true spatially resolved value.

Data

GOME-NO_2: GOME is a nadir sensor onboard on ERS-2 satellite launched by ESA in 1995, observing UV/Visible spectra at ~LT10:30 (over northern mid-latitudes) with a footprint of 40km×320km. Several groups have retrieved tropospheric NO_2 VCD from GOME spectra using Differential Optical Absorption Spectroscopy (DOAS). We used the data set that was retrieved by the IUP/University of Bremen [Richter et al., 2005]. We exclusively used GOME pixels with a cloud fraction < 0.2, as determined using the Fast Retrieval Scheme for Clouds from the O_2 A-band (FRESCO) algorithm.

Surface measurements of NO_2 VMR: The air-monitoring network more than 1000 stations measures the surface NO_2 VMR every hour in Japan. The instrument for the measurement of NO_2 utilizes a colorimetric determination by Saltzman's reagent. Since GOME observed NO_2 at ~LT10:30 over Japan, the surface NO_2 values were also averaged between LT 10:00 and LT11:00.

Scaling the surface NO2 VMR into tropospheric VCD using CTM: Surface VMR was scaled into tropospheric VCD for quantitative comparison with GOME-NO_2, which is also tropospheric VCD. The scaling factor that converts the surface VMR into the tropospheric VCD, was calculated by a regional CTM, CMAQ/REAS (horizontal resolution: 80X80 km, 14 layers up to resolution: 3 h).

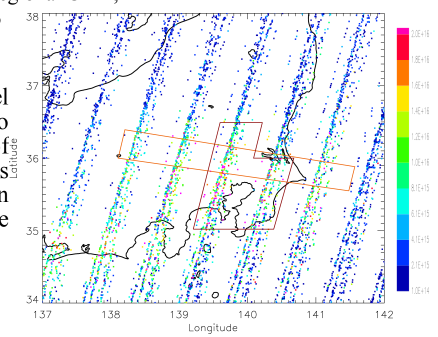


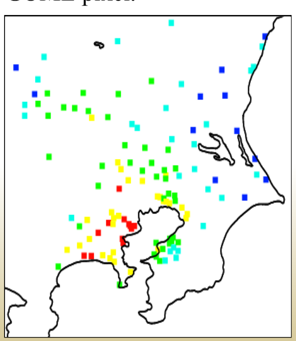
Model VMR at the surface: χ_s
Shaded area: *VCD*
Scaling factor: VCD/χ_s
Observed VMR at the surface: χ_{obs}

Scaled VCD: $\chi_{obs} \times (VCD/\chi_s)$

Method

Selecting of GOME pixels: Locations of the GOME pixel centers over central Japan in the period January 1996 to June 2003. The pixel colors indicate the concentration of tropospheric NO2 VCD. We used the pixels with centers located within the polygon surrounded by the solid brown line. The orange rectangle indicates an example of a single GOME pixel.



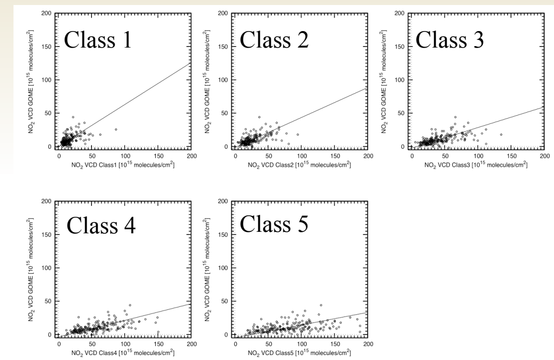


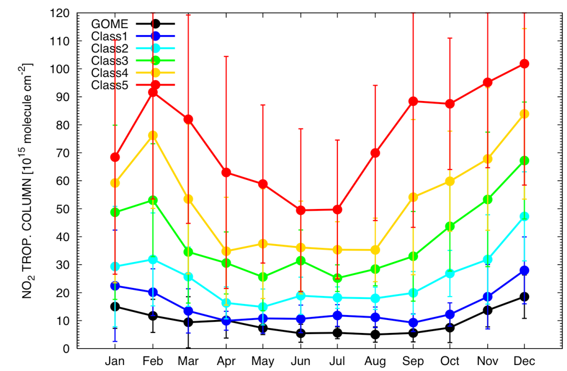
Class	Number of Stations	Average NO_2 [ppb]
1	12	<9.84
2	28	9.84-15.41
3	40	15.41-22.51
4	28	22.51-30.06
5	12	>30.06

Classification of the stations: Ordóñez et al. [2006] proposed a classification of surface stations into several groups according to their pollution levels to better represent the horizontal distribution of surface NO_2. To implement this classification, we calculated the average NO_2 VMR at each station over the entire period of the analysis. We regarded these averages as a measure of the pollution level for each station and sorted the stations into five group.

Results

We calculated a scaled tropospheric NO_2 VCD for each pollution level of the classification for the monitoring stations. The scaled tropospheric NO_2 VCD distributions of the relatively unpolluted groups were more consistent with GOME observations than were those of the highly polluted groups; the slopes of the weighted orthogonal regressions were closer to unity for the former. Hence, the GOME observations represent the behavior of NO_2 more closely at the relatively unpolluted stations than at the highly polluted stations.





Discussion

The GOME-NO_2 had the best quantitative correspondence with the Class 1 data. However, GOME still underestimated the tropospheric NO_2 VCD. Ordóñez et al. [2006] found the best quantitative correspondence in the Class 2 (slightly polluted) group, for which the average NO_2 VMR was between 18.58 and 26.16 ppbv. This level roughly corresponded to Class 3 (average polluted) group in the present study. Therefore, the values of GOME-NO_2 over Tokyo tend to be lower than those over northern Italy against a given VMR of the surface measurements. There are several possible explanations for this discrepancy.

- Tokyo is situated in a coastal area with a gulf, so that GOME pixels centered there always contain some ocean regions, where NO_2 concentration is much smaller than that over land.
- The pollution around Tokyo is very spatially concentrated; thus, the surrounding rural region can also contaminate the data. The influence of such factors in the GOME observations would be small in northern Italy, where the region of highest pollution is oriented in the direction of the GOME scan, reducing the dilution effect.

Conclusions:

GOME was successful in observing the behavior of NO_2 near the surface level in the Tokyo region, Japan. The quantitative comparison indicated that the GOME observations represent the behavior of NO_2 more closely at the relatively clean stations than at the highly polluted stations in the network of air-quality monitoring. The ocean and rural regions contaminating GOME pixels could reduce the observed NO_2 concentration from its true spatially resolved value.