

Comparison of tropospheric NO₂ 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 NO₂ to test whether satellite observations could successfully detect the behavior of tropospheric NO₂. We found that the GOME observations represent the behavior of NO₂ 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 NO₂ concentration from its true spatially resolved value.

Data

GOME-NO₂: 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. We used the data set 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 O₂ A-band (FRESCO) algorithm.

Surface measurements of NO₂ VMR: The air-monitoring network more than 1000 stations measures the surface NO₂ VMR every hour in Japan. The instrument for the measurement of NO₂ utilizes a colorimetric determination by Saltzman's reagent.

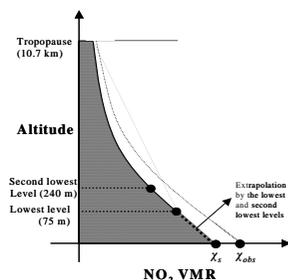
Scaling the surface NO₂ VMR into tropospheric VCD using CTM: Surface VMR was scaled into tropospheric VCD for quantitative comparison with GOME-NO₂, which is also tropospheric VCD. The scaling factor that converts the surface VMR into the tropospheric VCD, was calculated by a regional CTM, CMAQ/REAS (horizontal resolution: 80x80 km, 14 layers up to 23 km, time resolution: 3 h).

Method

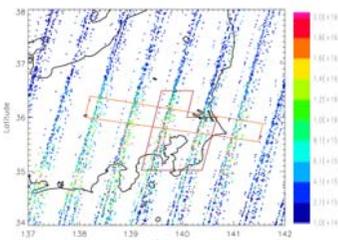
Selecting of GOME pixels: Locations of the GOME pixel centers over central Japan in the period January 1996 to June 2003. The pixel colors indicate the concentration of tropospheric NO₂ VCD. We used the pixels with centers located within the polygon surrounded by the solid brown line. The orange rectangle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

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 NO₂. To implement this classification, we calculated the average NO₂ 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 groups.

Conclusions: GOME was successful in observing the behavior of NO₂ near the surface level in the Tokyo region, Japan. The quantitative comparison indicated that the GOME observations represent the behavior of NO₂ 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 NO₂ concentration from its true spatially resolved value.



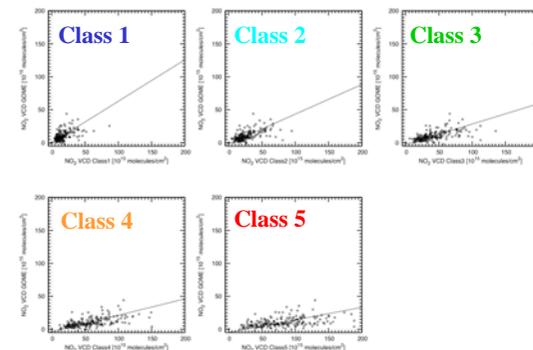
Model VMR at the surface: χ_s
 Shaded area: VCD
 Scaling factor: VCD/χ_s
 Observed VMR at the surface: χ_{obs}
 Scaled VCD: $\chi_{obs} \times (VCD/\chi_s)$



Class	Number of station	Average NO ₂ [ppbv]
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

Results

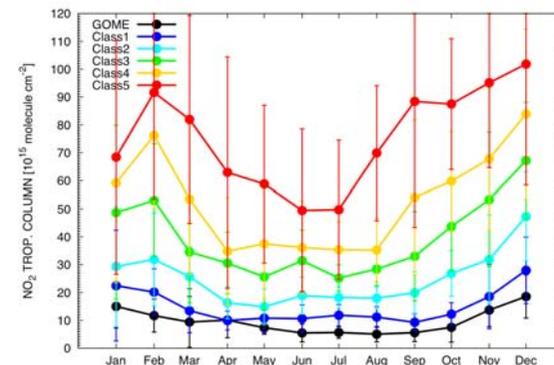
We calculated a scaled tropospheric NO₂ VCD for each pollution level of the classification for the monitoring stations. The scaled tropospheric NO₂ VCD distributions of the relatively unpolluted groups were more consistent with GOME observations than were those of the highly polluted groups; the slopes of the weighted orthogonal regressions were closer to unity for the former. Hence, the GOME observations represent the behavior of NO₂ more closely at the relatively unpolluted stations than at the highly polluted stations.



Discussion 1

The GOME-NO₂ had the best quantitative correspondence with the Class 1 data. However, GOME still underestimated the tropospheric NO₂ VCD. Ordóñez et al. [2006] found the best quantitative correspondence in the Class 2 (slightly polluted) group, for which the average NO₂ 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-NO₂ 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 NO₂ 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.



Discussion 2

The spatial resolution of the model for scaling factors can affect the results of a quantitative comparison, because the NO₂ distribution has high spatial heterogeneity. The comparison of NO₂ vertical profiles from 5-km-grid and 80-km-grid models' runs showed that the scaling factor of the 5-km-grid simulation run was about 30-100% of the 80-km-grid simulation run. Therefore, the model resolution can affect the results of such quantitative comparisons.

