A regional OMI NO_2 product for the Pearl River Delta region

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Background and Motivation

The Pearl River Delta (PRD) region is a highly industrialized and urbanized region (see Fig. 1) in which low air quality is a severe problem. Since the global satellite products underestimate NO_2 concentrations [e.g. 1], we present a new regional NO_2 product from the Ozone Monitoring Instrument (OMI):

- Recalculation of air mass factors (AMF) using ancillary parameters with a high spatial-temporal resolution.
- Profiles of aerosol extinction coefficients from the CMAQ chemistry transport model.
- Validation with NO_2 ground mixing ratios measured by the PRD Regional Air Quality Monitoring (RAQM) network.

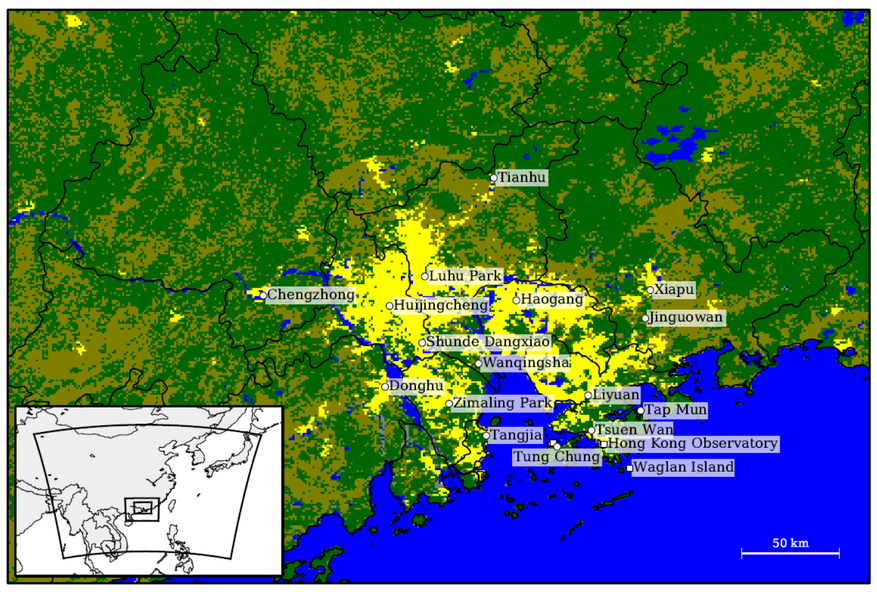

Fig. 1: The PRD region with MODIS land categories: forest and crop land (green), urban (yellow) and water (blue). Stations of the RAQM network (circles) and the Hong Kong Observatory (squares).

Small figure: CMAQ model domains.

Regional OMI NO_2 Product

Tropospheric NO_2 vertical column densities (V_{trop}) were newly computed using recalculated air mass factors (AMF):

$$V_{trop} = \frac{S_{trop}}{A_{trop}} \quad \text{with} \quad \mathrm{A_{trop}} = \frac{\sum_k \alpha_k m_k V_k}{\sum_k V_k},$$

- S_{trop}: tropospheric slant column density
- α_k: temperature correction coefficient
- m_k: scattering weight or box AMF
- V_k: partial NO_2 vertical column density (VCD)

Tab. 1: Source of ancillary parameters used for AMF calculations

surface reflectance	MODIS black-sky albedo (0.5 degree)
cloud pressure and fraction	OMI cloud product
surface pressure & temperature profiles	WRF and CMAQ modelling system ($3\times3km^2$ spatial resolution, 3-hourly averages during OMI overpass)
NO_2 profiles	
aerosol optics	

NO_2 Profiles and Aerosol Parameterizations

Four different aerosol parameterizations were tested (PRD-X):

1. No explicit aerosols but implicitly included by the OMI cloud product
2. CMAQ ground level extinction coefficient are used as mean value for planet boundary layer (0-2km).
3. Profiles of aerosol extinction coefficients are computed with the IMPROVE formula (Fig. 2).
4. As in Case 3 but the cloud fraction is reduced using an empirical formula to correct for the aerosol sensitivity of the OMI cloud product [2].

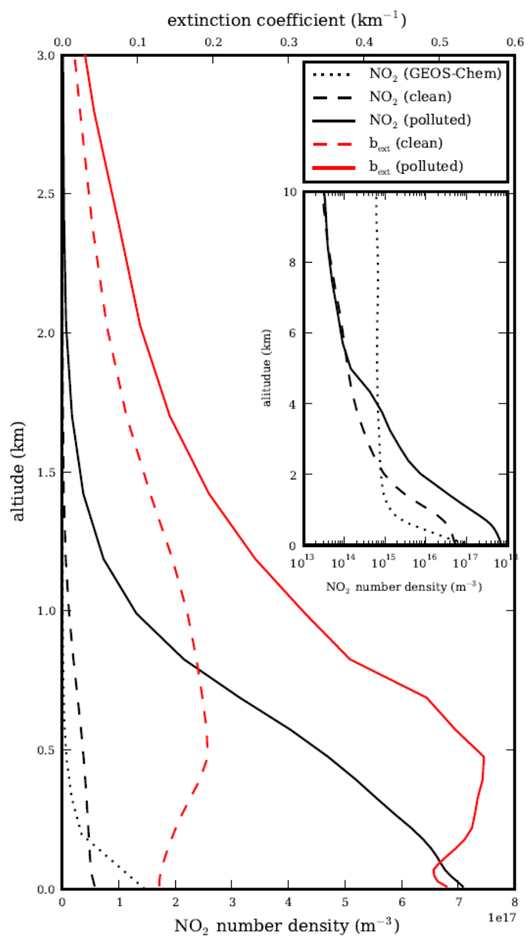

Fig. 3: Averaged CMAQ NO_2 and extinction coefficient profiles under “clean” and “polluted” conditions. Annual GEOS-Chem NO_2 profile for Hong Kong (2°×2.5° spatial resolution).

Impact of Ancillary Parameters

Influence on AMF using a test case (see Fig. 2):

- CMAQ NO_2 profile: ~40% reduced (compared to GEOS-Chem profile)
- surface reflectance: ~5..10% reduced (compared to OMI LER climatology)
- aerosol profiles: 10..15% reduced (PRD-4 compared to PRD-1)

NO_2 VCDs were compared with the NASA standard product (SP2):

- PRD-1: +(27±39)%
- PRD-4 : +(31±38)%
- similar spatial distributions but differences can be seen in a pixel-by-pixel comparison (Fig. 3)

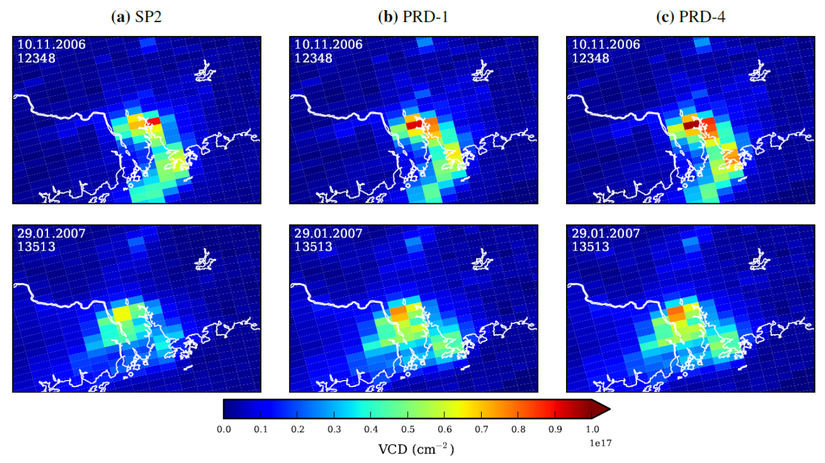

Fig. 3: Two example orbits of OMI NO_2 distributions for SP2, PRD-1 and PRD-4.

Gridding Algorithm & Conversion to Ground Level

- NO_2 VCDs were projected on a longitude-latitude grid using a new gridding algorithm which reconstructs the spatial distribution by an parabolic spline surface (available at: https://github.com/gkuhl/omi) [3].
- VCDs were converted to ground level mixing ratios using the CMAQ NO_2 profile shapes.

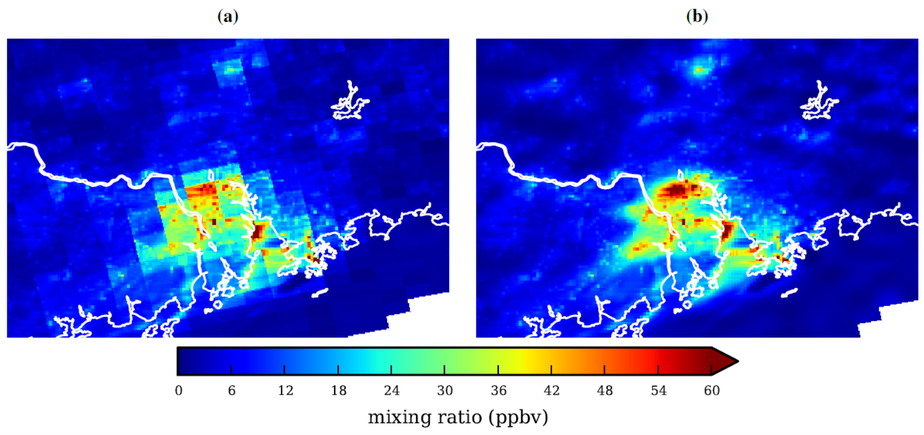

Fig. 4: OMI ground mixing ratios from orbit number 13513 on 29.1.2007 comparing (**a**) a “standard” and (**b**) the new gridding algorithm.

Validation with Ground Network

Main findings:

- The correlation coefficients are low for both satellite products due to the complex spatial distribution and the low resolution of the satellite instrument ($13\times24km^2$ at nadir).
- In the new product (PRD-4), the mean bias (MB) is reduced by 26 percentage points from -41% to -15% using all 16 stations (see Fig. 1).
- In Foshan & Guangzhou[b], the CMAQ model underestimates NO_2 concentrations by about 40%.
- As a consequence, OMI VCDs can be still underestimated by 10 to 20% because of the influence of the model parameters on the AMF (NO_2 profile shape and aerosols).

Tab. 2: Results of validation of OMI with RAQM network

	Hong Kong & Shenzhen[a]			Foshan & Guangzhou[b]		
	r	MB (ppbv)	NMB (%)	r	MB (ppbv)	NMB (%)
SP2	0.19	-17.5	-54	0.47	-14.3	-48
PRD-1	0.24	-8.8	-27	0.41	-10.7	-36
PRD-4	0.24	-7.4	-23	0.46	-8.7	-29
expected*	0.25	-4.6	-16	0.67	-1.6	-12

[a] Liyuan, Tap Mun, Tsuen Wan and Tung Chung
[b] Huijingcheng, Luhu Park, Shunde Dangxiou and Wanqingsha
* the influence of the OMI ground pixel size (area averaging) was estimated by comparing CMAQ data, which have been averaged to OMI resolution, with high-resolution CMAQ data ($3\times3km^2$)

Conclusions

- The new regional OMI product can be used to study the spatial distribution and the magnitude of NO_2 VCDs on a regional scale.
- The low bias can be achieved with high-resolution ancillary parameters of NO_2 profiles, surface reflectance and aerosol profiles.
- The regional product can be used for studies where unbiased concentrations are important, for example, in air pollution studies.

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