NO\textsubscript{2} lifetime and emissions of hotspots in polluted background estimated by satellite observations

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SUMMARY

We present a new method to quantify NO\textsubscript{2} emissions and corresponding atmospheric lifetimes from OMI NO\textsubscript{2} observations together with ECMWF wind fields without further model input for sources located in polluted background. NO\textsubscript{2} patterns under calm wind conditions are used as proxy for the spatial patterns of NO\textsubscript{2} emissions, and the effective atmospheric NO\textsubscript{2} lifetime is determined from the change of spatial patterns measured at larger wind speeds. Emissions are subsequently derived from the NO\textsubscript{2} mass above background integrated around the source of interest. Lifetimes and emissions are estimated for 17 power plants and 53 cities located in non-mountainous regions across China and the US. The derived lifetimes for non-mountainous sites are 3.8 ± 1.0 hours on average with ranges of 1.8 to 7.5 hours. The derived NO\textsubscript{2} emissions show good agreement with bottom-up inventories for power plants and cities.

WIND DEPENDENCY OF NO\textsubscript{2} COLUMN DENSITIES

We use Harbin (45.8°N, 126.7°E), the capital of Heilongjiang province, China, with a population of about 6 million (city) to 10 million (greater area) inhabitants, to demonstrate the approach. The outflow plume of NO\textsubscript{2} from Harbin is not as clear as that from isolated sources (e.g. Riyadh in Beirle et al. (2011)), due to the interferences from surrounding sources. But the spatial pattern of their difference (Fig. c) still clearly shows an outflow pattern, consistent with ECMWF winds.

FITTING PROCEDURE

Motivation: The method can only represent a single “point source” convolved with a Gaussian. It worked properly for 9 isolated hot spots requiring high NO\textsubscript{2} columns with clean background within some hundred kilometers. But it cannot be applied to hot spots around multiple interfering sources, like Harbin.

Idea: use the NO\textsubscript{2} patterns observed under calm conditions as proxy of emission patterns

Model Function: $N(x) = a \times e^{-\frac{c}{2}\times(x+b)}$

$\epsilon(x)$: a truncated exponential function
$a$: a scaling factor
$b$: an offset

Model Function: $g(x) = \frac{a}{\sqrt{2\pi}} \times e^{-\frac{(x+b)^2}{2c^2}}$

$c$: the standard deviation of the Gaussian $g(x)$
$b$: a possible linear gradient in the background
$\epsilon$: an offset

Emotions

Emission=Mass/Lifetime

RESULTS

We applied our modified method for determining NO\textsubscript{2} lifetimes and emissions to 17 power plants (black circles) and 53 cities (blue circles) across China and the US.

Average NO\textsubscript{2} TVCDs for 2005–2013

DISCUSSIONS

We compared the derived NO\textsubscript{2} emissions to bottom-up emission inventories for all 17 power plants and 53 cities.

Power Plant: the relative is 5% ± 27% (mean ± standard deviation) on average
City: the relative is 9% ± 49% (1% ± 46%) and 20% ± 51% for China and the US respectively

We compared the representations of China’s urban emissions between MEIC and EDGAR

Comparison for investigated Chinese cities

Major differences:

- Power plants: MEIC used CPED, while EDGAR used CARMA
- Industrial activities: MEIC first downscaler provincial totals to counties using industrial GDP, and then allocate county emissions to grids with population density, while EDGAR directly distributed provincial emissions by population density
- Vehicles: MEIC allocated on-road emissions by vehicle and road type using the China Digital Road-network Map; while EDGAR used the product of population density and road network

We compared emissions derived based on the individual fitted lifetimes and the mean lifetime of all sites (3.7 hours)

REFERENCE