Trends in tropospheric NO$_2$ columns over Europe and the effect of the economic crisis observed from the Ozone Monitoring Instrument

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European NO$_2$ emissions 2005-2010

The EMEP CEIP "expert emissions inventory" reports NO$_2$ emissions reductions of 5-40% between 2005 and 2010. The Table below lists estimated trends in NO$_2$ emissions for a number of northwest European countries. The reductions mostly reflect stricter motor vehicle standards with diminishing returns imposed by the European Union (Euro 4&5, and Euro IV &V emission standards).

<table>
<thead>
<tr>
<th>Country</th>
<th>EMEP CEIP Trend (2005-2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>-4.5 %/yr</td>
</tr>
<tr>
<td>France</td>
<td>-2.6 %/yr</td>
</tr>
<tr>
<td>Germany</td>
<td>-3.2 %/yr</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-1.0 %/yr</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-6.3 %/yr</td>
</tr>
</tbody>
</table>

Ground-based monitoring networks in northwestern Europe also observe reductions in NO$_2$ concentrations but urban NO$_2$ levels do not follow the NO$_2$ reductions. This could be due to:

- A shift towards higher NO$_2$/NO ratios in NO$_2$ emissions, because of increasing numbers of diesel vehicles [Carslaw, 2005].
- Increases in the urban background ozone, favouring NO$_2$ over NO. Especially close to strong sources [Keuken, 2009].

Because of these difficulties, and because monitoring trends with ground-based instruments is difficult given the considerable differences in spatial representativity between ‘background’, ‘sub-urban’, and ‘urban’ stations, we turn to satellite retrievals. Satellite measurements cover all of Europe, use one consistent retrieval method, and provide excellent spatial representativity.

Kolmogorov-Zurbenko filtering of OMI NO$_2$ data

Here we use DOMINO v1.02 data [Boersma et al., 2007] between October 2004 and December 2010. Only measurements with cloud radiance fractions ≤ 50% have been selected, and pixels affected by the row anomaly (rows 27-44 and 53-54) were excluded for the entire 2004-2010 time period.

The Kolmogorov-Zurbenko filtering removes high-frequency variability (weekly cycle, seasonal variability), while retaining the long-term trend in tropospheric NO$_2$.

\[
\text{Smoothened OMI NO}_2 = \frac{1}{m^2} \sum_{i=-(m-1)/2}^{(m-1)/2} \text{Original, daily OMI NO}_2 \text{column}
\]

We use \( m = 365 \) days and apply the filtering twice, thus suppressing all variability with a period < 1.4 yr.

The Figure below shows the KZ-filtered average OMI NO$_2$ column over Europe for August 2005 (upper left panel), plus the differences between subsequent years and 2005. Blue colors indicate relative reductions, red increases.

KZ-filtered NO$_2$ above Amsterdam as a function of days since 1 January 2005:

- Decrease in NO$_2$ emissions for seasonal cycle in NO$_2$.
- Strong reductions after 2007 in northwestern Spain associated with DeNox installation at local power plants.

Some conclusions:

- NO$_2$ concentrations over Europe decrease continuously during 2005-2010.
- Reductions in NO$_2$ emissions or meteorology/photocemistry? What happened at day 1500 (late 2008)?

Reductions in OMI NO$_2$ over Amsterdam

We test our approach for two scenarios. In scenario A we assume a constant NO$_2$ emission change rate, and in scenario B we use an acceleration of the emissions change rate in October 2008 and a deceleration in March 2010 to capture the effects of the economic crisis.

Scenario B matches the observed NO$_2$ change rate best. Preliminary results indicate that our regression model captures 72% (scenario A: 21%) of the observed variability, and that interannual changes in temperature and precipitation explain 15% of the observed NO$_2$ change rate. Over Amsterdam, NO$_2$ decreased at -2%/yr, but during the 2008-2009 crisis, the rate of decrease was as high as -7%/yr. We find similar results for Rotterdam and the nearby Ruhr Area in Germany.

References


Keuken, M. M. Rozema, and S. van den Brink: Trends analysis of urban NO$_2$ concentrations and the importance of direct NO$_x$ emissions versus source NO$_x$ equilibrium, Atmos. Environ., 42, 4793-4801, 2008.