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_x emissions 2005-2010

The EMEP CEIP "expert emissions inventory" reports NO_x emissions reductions of 5-40% between 2005 and 2010. The Table below lists estimated trends in NO_x 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).

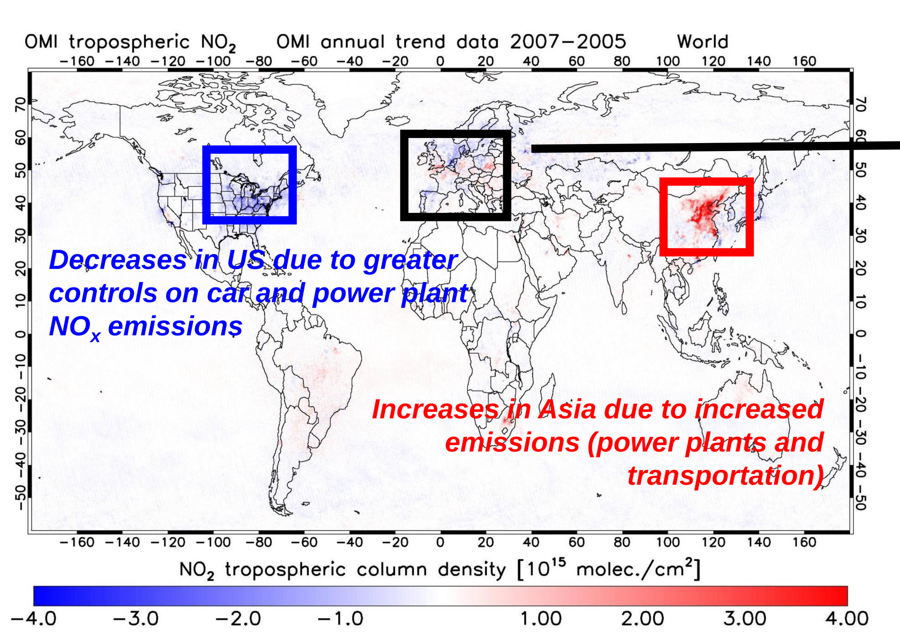
Country	EMEP CEIP Trend (2005-2010)
Belgium	-4.5 %/yr
France	-2.6 %/yr
Germany	-3.2 %/yr
Netherlands	-1.0 %/yr
United Kingdom	-6.3 %/yr

Ground-based monitoring networks in northwestern Europe also observe reductions in NO_x concentrations but urban NO_2 levels do not follow the NO_x reductions. This could be due to:

- A shift towards higher NO_2:NO ratios in NO_x emissions, because of incrreasing 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.

Differences in OMI NO_2 2007-2005



No clear trend in simple comparison between 2007 and 2005 over Europe

Need more sophisticated trend analysis to account for seasonal cycle in NO_2.

Kolmogorov-Zurbenko filtering of OMI NO_2 data

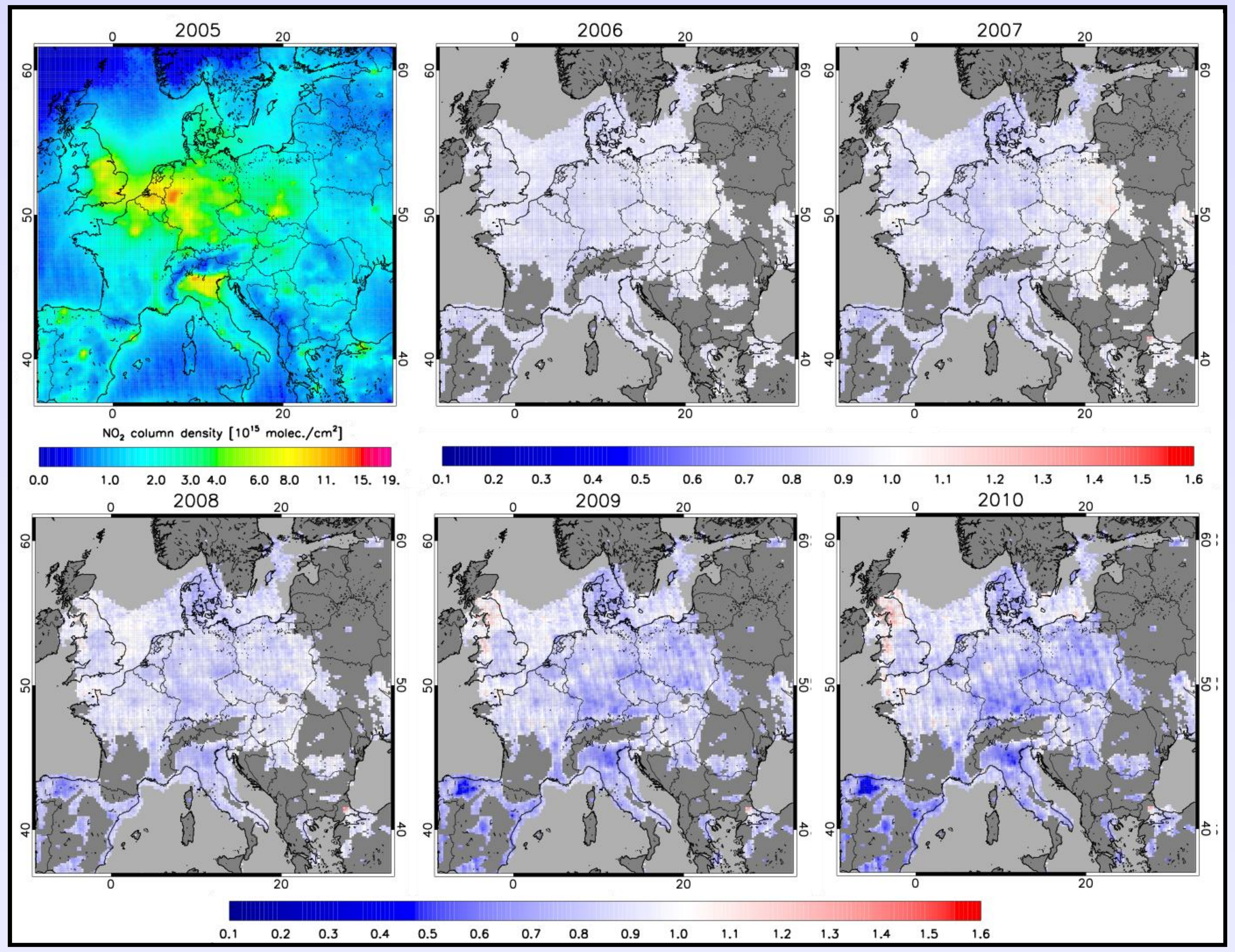
Here we use DOMINO v1.02 data [Boersma et al., 2007] between October 2004 and December 2010. Only measurements with cloud radiance fractions < 50% have been selected, and pixels affected by the row anomaly (rows 27-44 and 53-54) were excluded for the entire 2004-2010 time period.

The Kolmogorov-Zurbenko filtering removes high-frequency variability (weekly cycle, seasonal variability), while retaining the long-term trend in tropospheric NO_2:

$$\underbrace{y_t}_{\text{Smoothed OMI } NO_2} = \frac{1}{m}\sum_{s=-(m-1)/2}^{s=(m-1)/2} \underbrace{x_{t+s}}_{\text{Original, daily OMI } NO_2 \text{ column}}$$

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

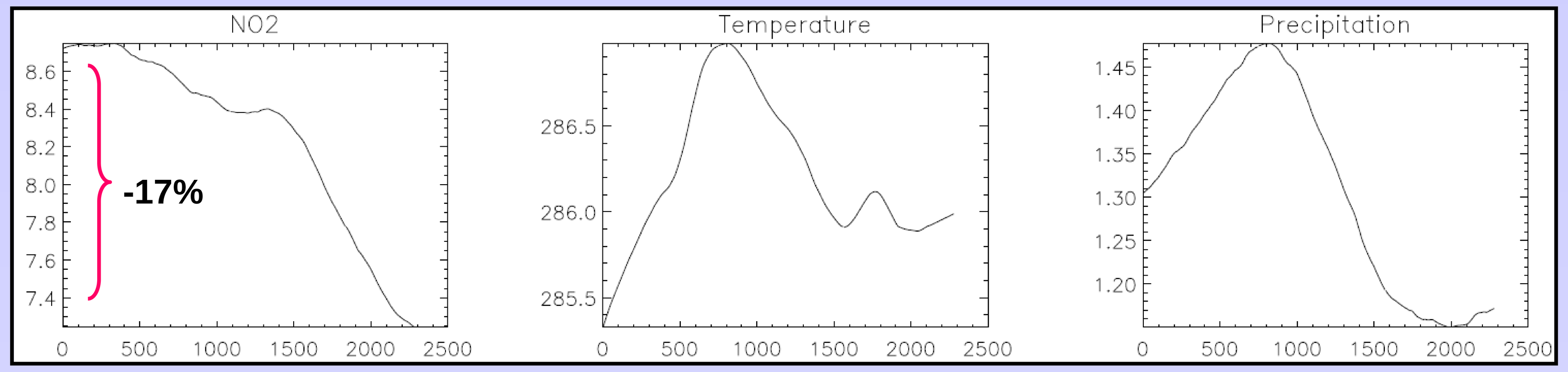
The Figure below shows the KZ-filtered average OMI NO_2 column over Europe for August 2005 (upper left panel), plus the differences between subsequent years and 2005. Blue colors indicate relative reductions, red increases.



Some conclusions:

- NO_2 concentrations over Europe decrease continuously during 2005-2010.
- Strong reductions after 2007 in northwestern Spain associated with DeNOx installation at local power plants.

Reductions in OMI NO_2 over Amsterdam



KZ-filtered tropospheric NO_2 above Amsterdam as a function of days since 1 January 2005.

KZ-filtered temperature above Amsterdam as a function days passed since 1 January 2005

KZ-filtered precipitation above Amsterdam as a function days passed since 1 January 2005

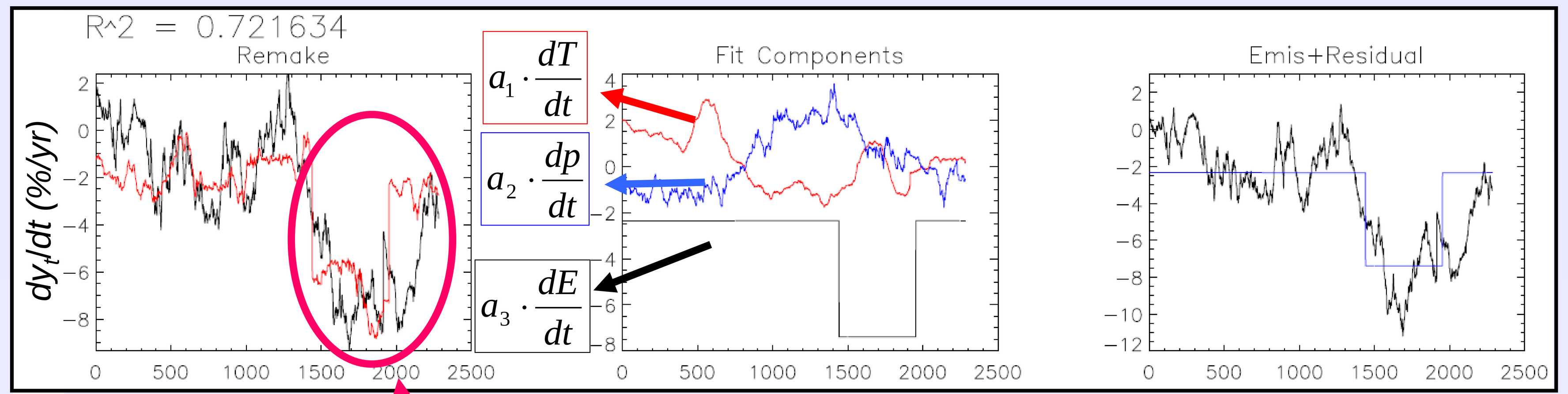
Are reductions in NO_2 the result of changes in NO_x emissions or meteorology/photochemistry? What happened at day 1500 (late 2008)?

The Figure above indicates that it is unlikely that the observed reduction in NO_2 originates from trends in temperature or precipitation alone. Nevertheless, temperature and precipitation are likely to influence the NO_2 concentrations. We use a simple multilinear regression model that relates changes in (KZ-smoothed) temperature (T), precipitation (p), and NO_x emissions (E) to the observed NO_2 columns. The fit coefficients a_i indicate the strength of the contribution to the NO_2 change rate over Amsterdam:

$$\frac{dy}{dt} = a_1 \cdot \frac{dT}{dt} + a_2 \cdot \frac{dp}{dt} + a_3 \cdot \frac{dE}{dt}$$

We test our approach for two scenarios. In scenario A we assume a constant NO_x 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 ±1.5% 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.



Economic crisis in Amsterdam observed from space

References

Carslaw, D. C., Evidence of an increasing NO_2/NO_x emissions ratio from road traffic emissions, *Atm. Environm., 39*, 4793-4801, 2005.

Keuken, M., M. Roemer, and S. van den Elshout, Trend analysis of urban NO_2 concentrations and the importance of direct NO_2 emissions versus ozone/NO_x equilibrium, *Atm. Environm., 43*, 4780-4783, 2009.