



Reductions in NO_2 Driven by Policy and Recession



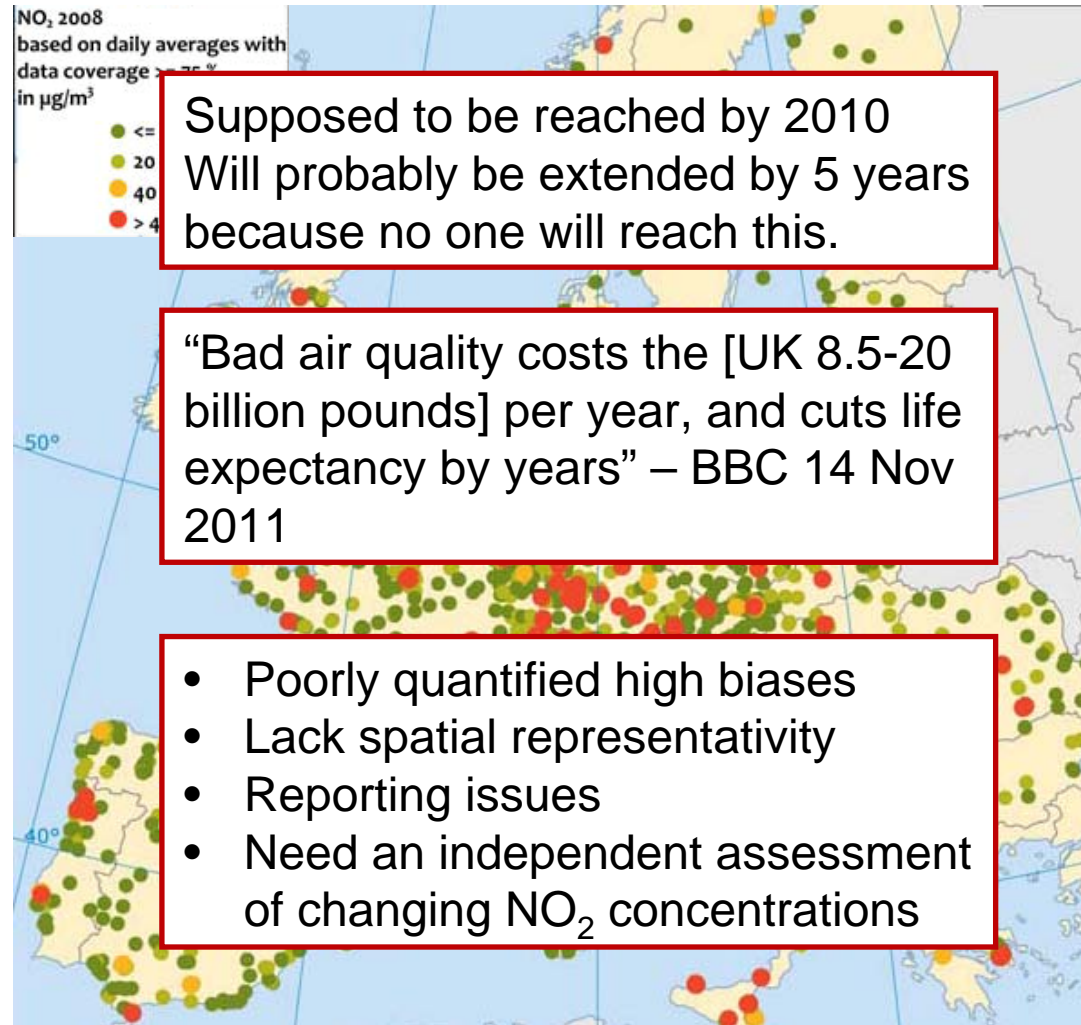
Patricia Castellanos¹ & K. Folkert Boersma^{1,2}

AK/CK Talk November 22, 2011

NO₂ Over Europe

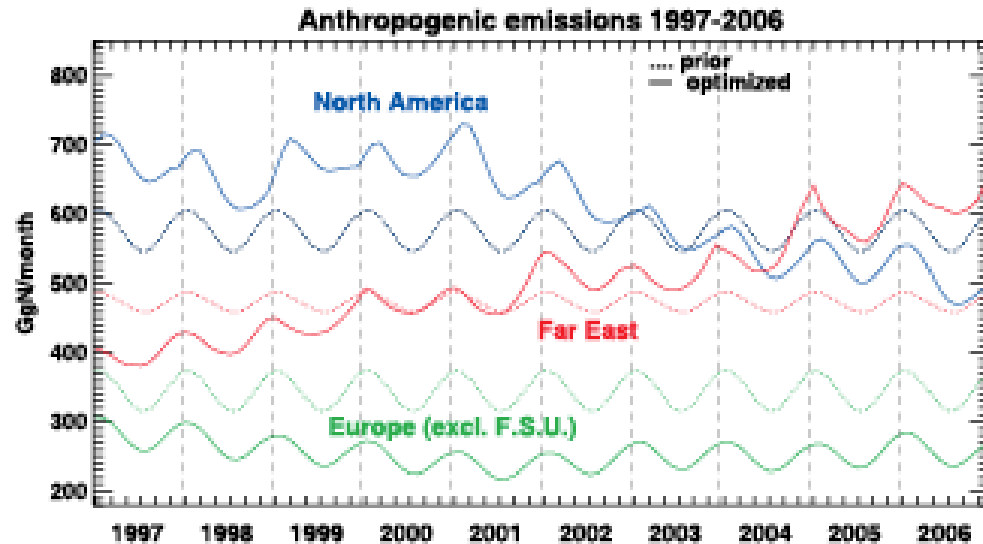
- Ozone precursor
- Contributes to aerosol formation
- Eutrophication of soil and water
- Acid deposition
- Toxic at high concentrations

2008 Annual Mean



NO₂ Trends From Space

- Monitor effectiveness of pollution abatement strategies
- Satellites provide
 - Global coverage
 - Independent & self-consistent time series



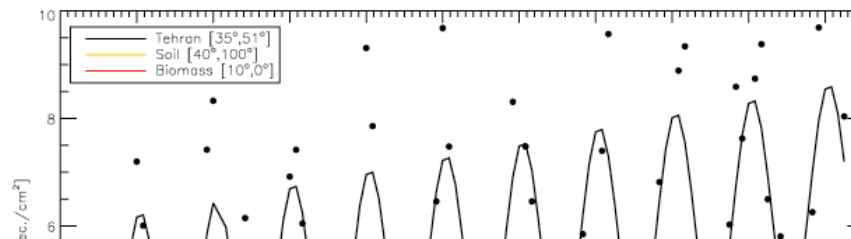
Stavrou [2008]

European NO₂ column trends in the literature

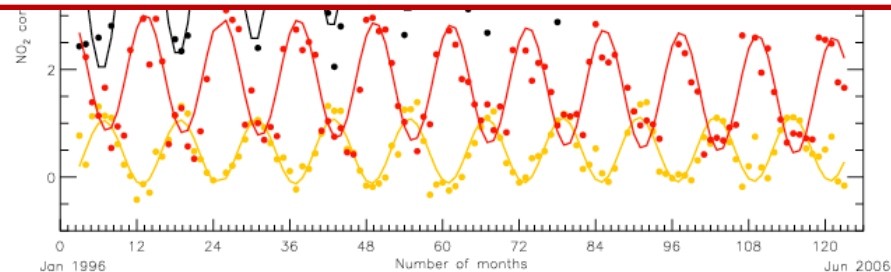
	Trend [% per year]	Time Period
Richter <i>et al.</i> [2005]	-3% to -4%	1996-2004
van der A <i>et al.</i>	A Few % Per Year	1996-2006
Konovalov <i>et al.</i> [2008]	-2% to -5%	1996-2005

NO₂ Column Trends

- Disparate summer and winter NO₂ lifetimes
 - Derive a trend from only one season or the annual mean
 - Fit a sinusoidal function or spline curve to the data



- Assume some regular seasonal variability
- By fitting to a linear trend you lose information in year-to-year variability



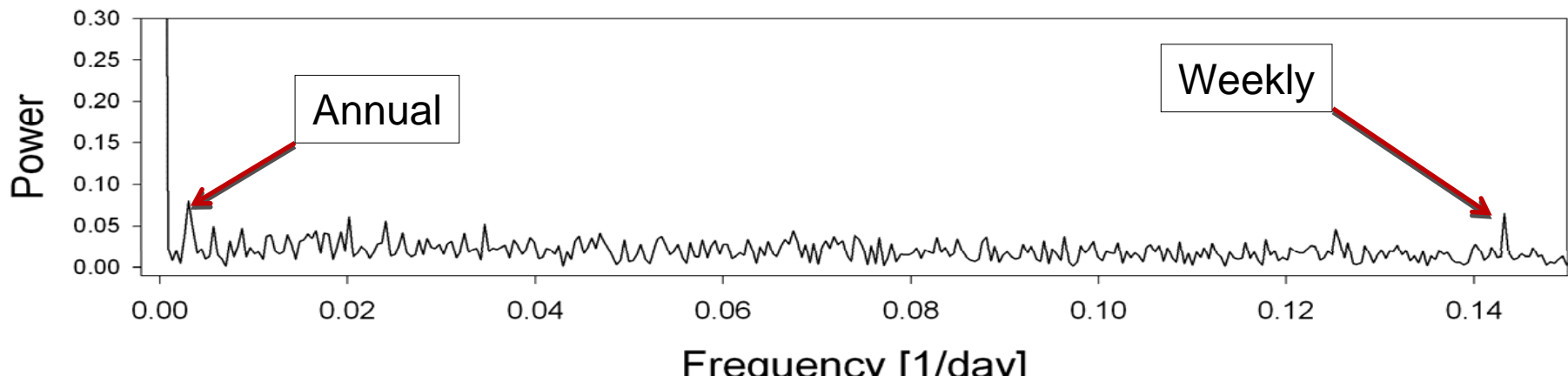
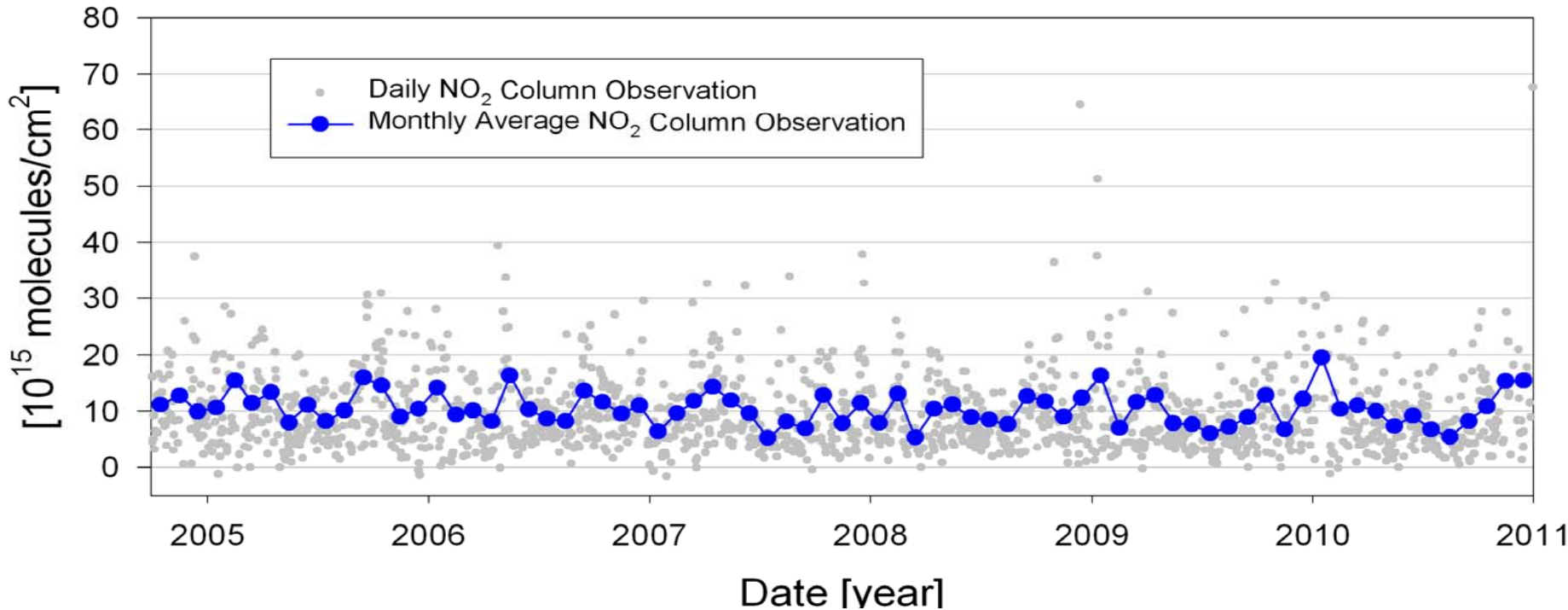
van der A [2008]

NO₂ Timeseries



Amsterdam

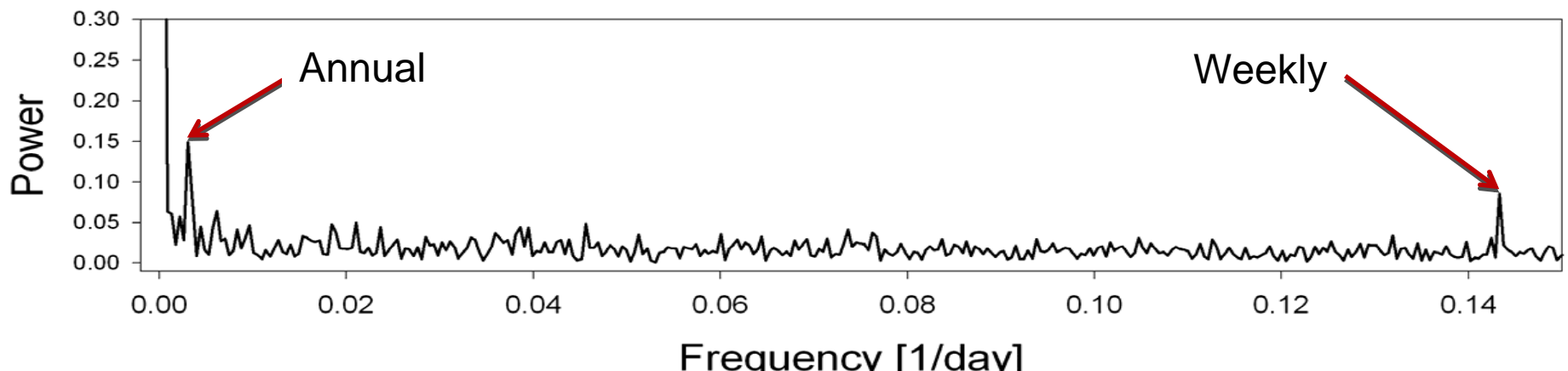
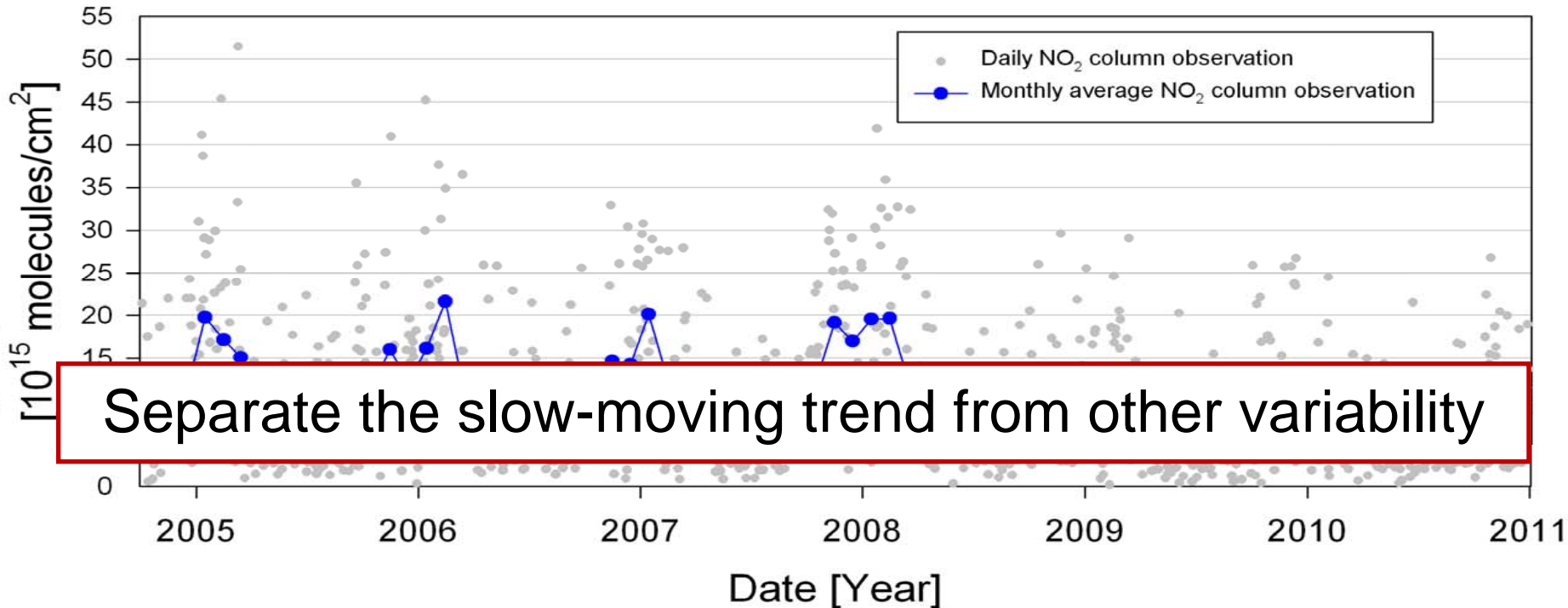
NO₂ Tropospheric Column



OMI NO₂ Timeseries

Madrid

NO₂ Tropospheric Column

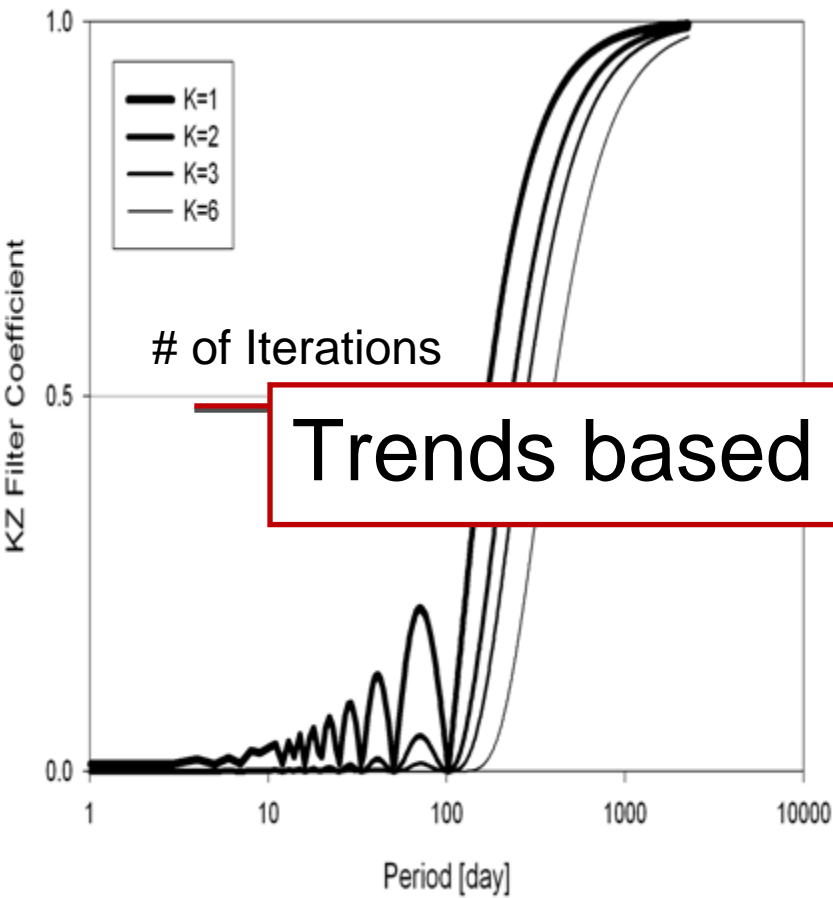


Frequency Separation – KZ Filter

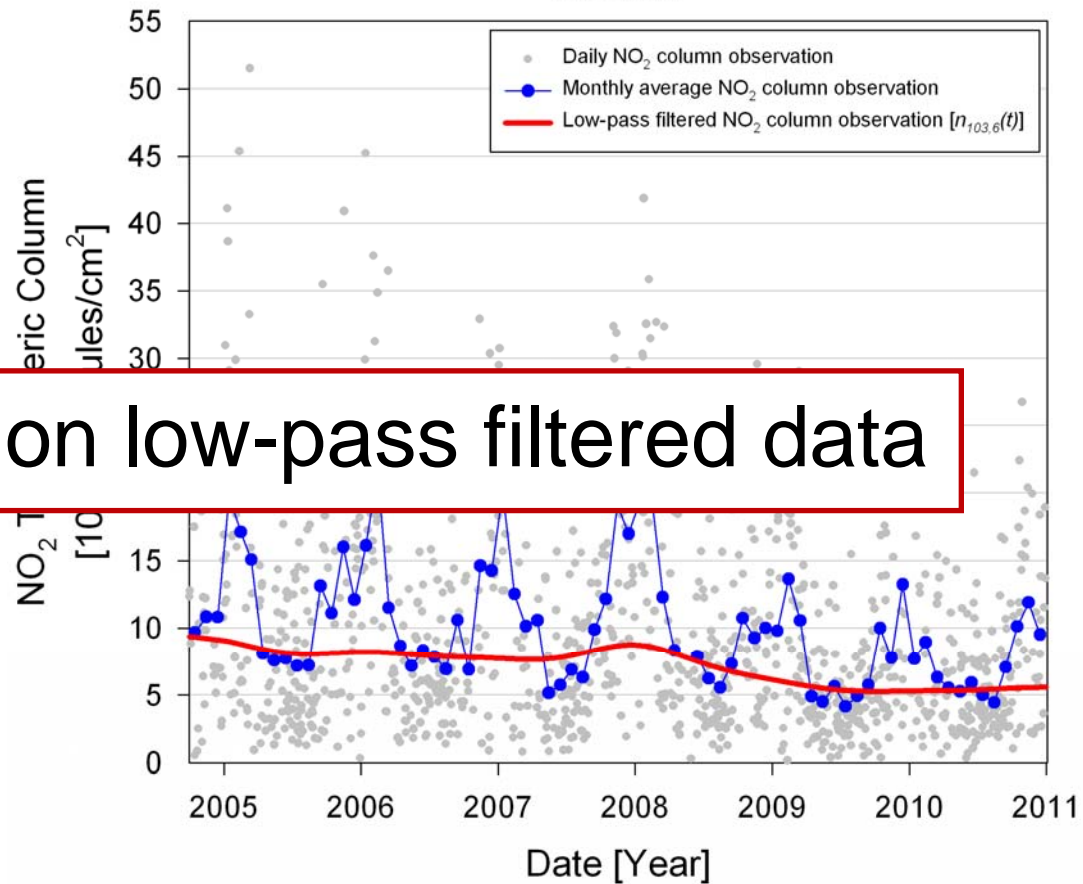
$$n_{m,k}(t) = \frac{1}{m} \sum_{s=-\frac{(m-1)}{2}}^{\frac{(m-1)}{2}} n(t+s)$$

K-iterations of a moving average

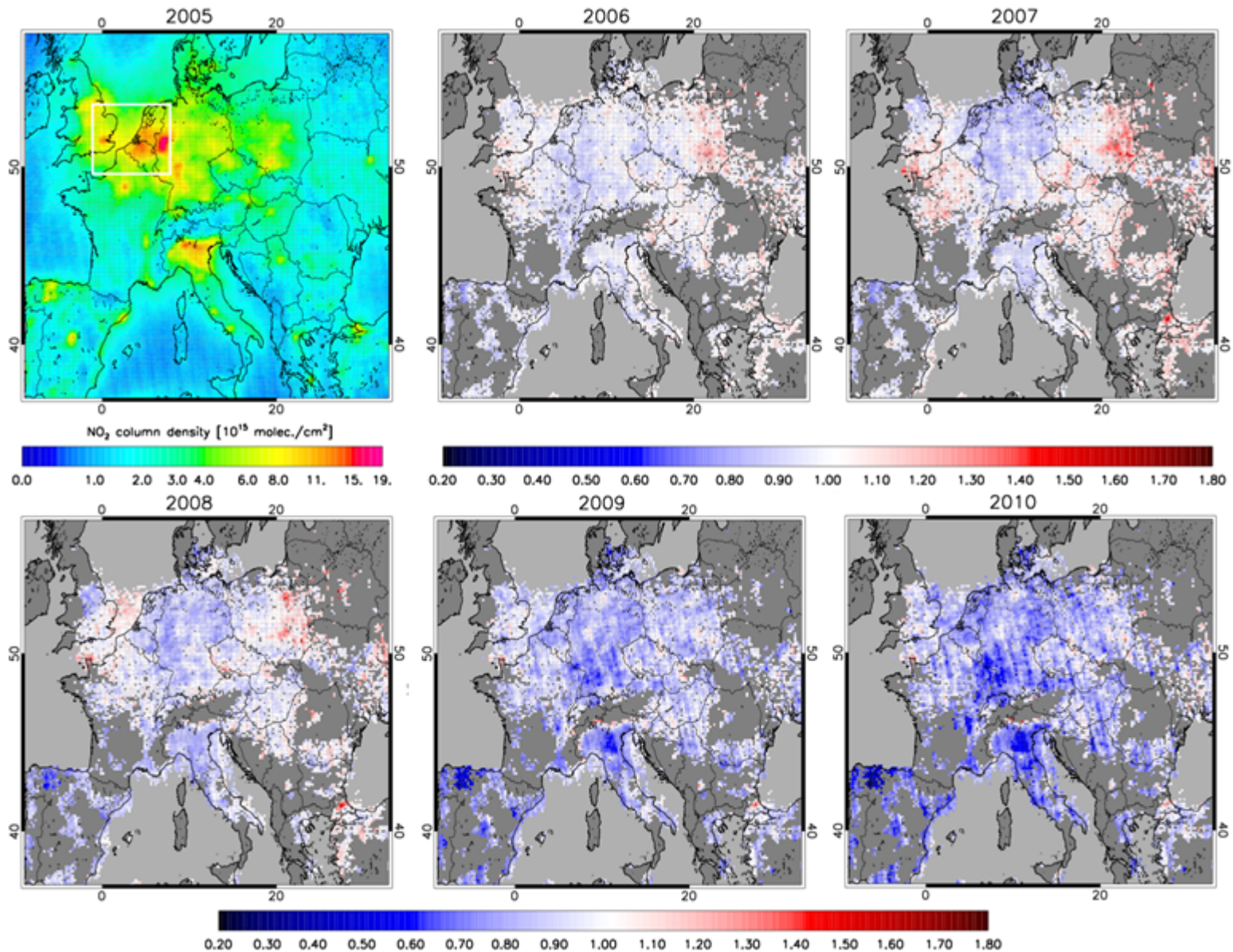
Transfer Function



Madrid

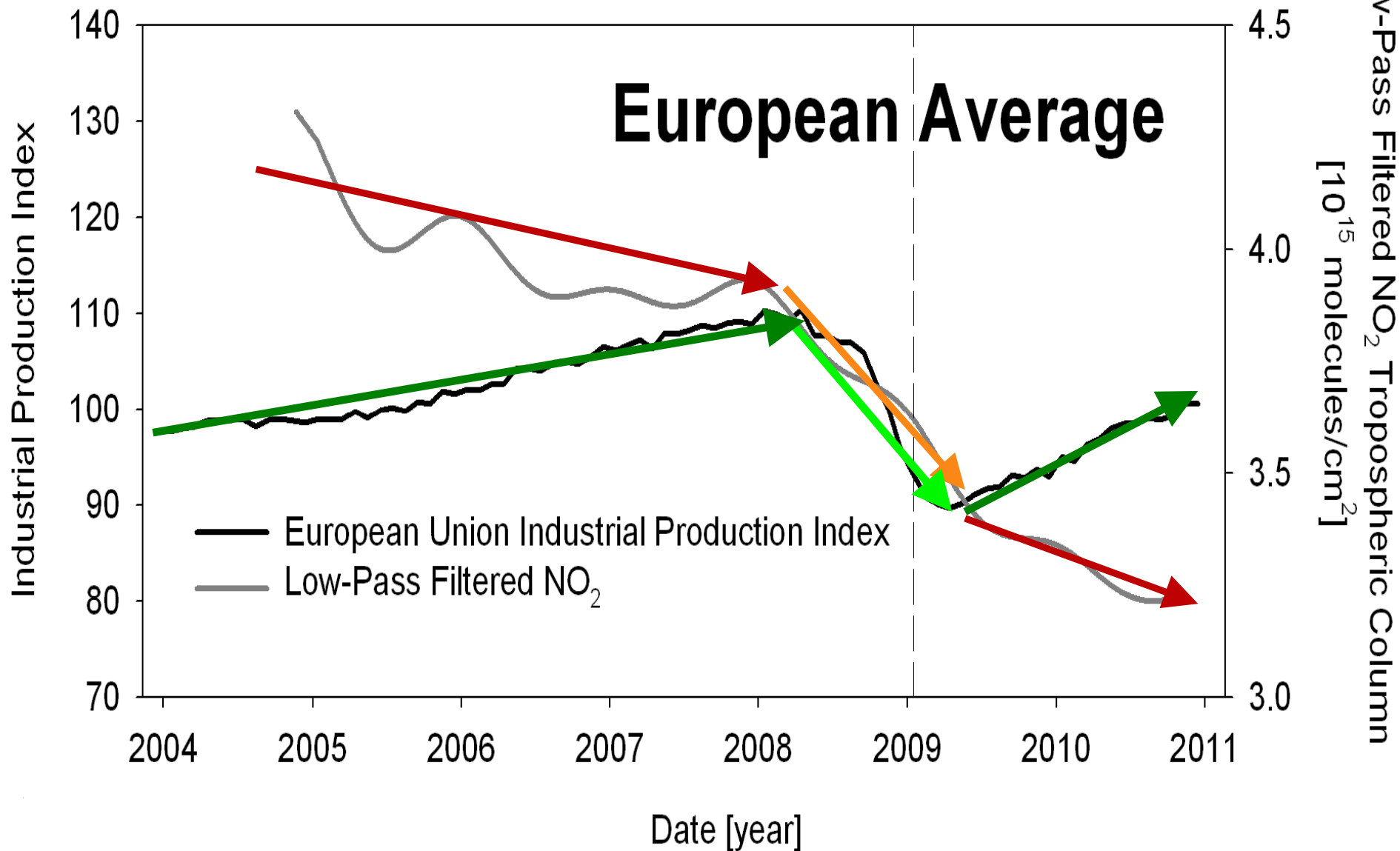


Low-pass Filtered NO₂: August





NO₂ Trends Relate to Economic Indicators

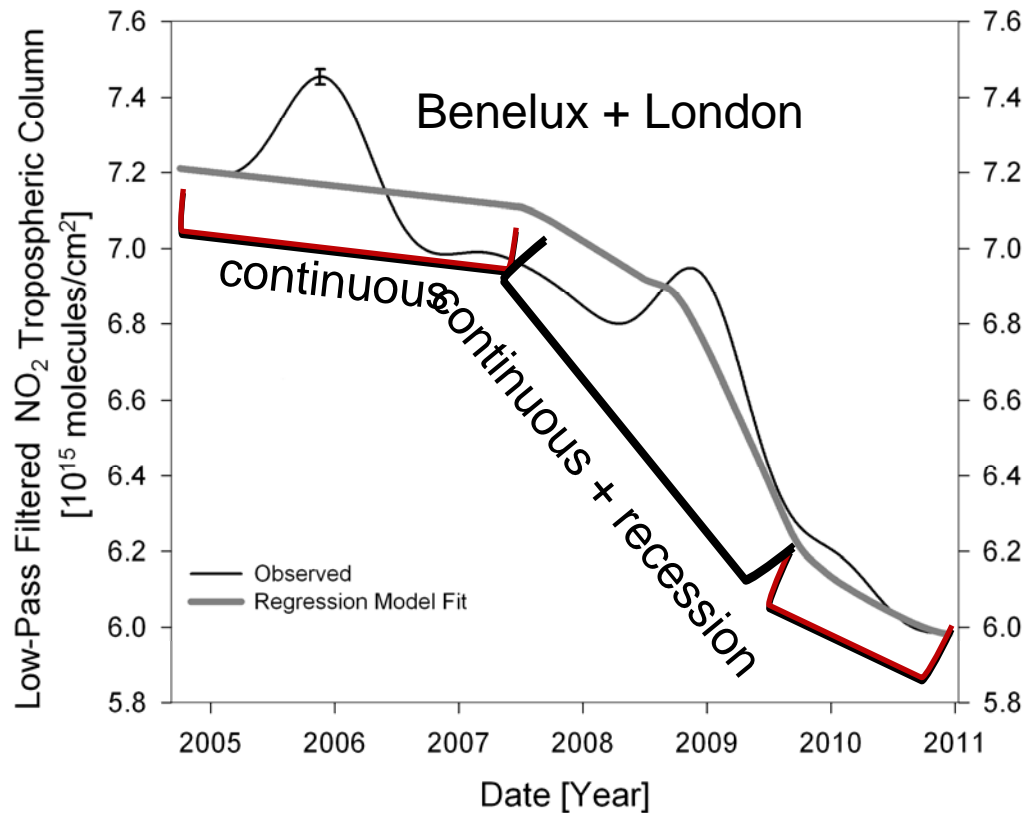


Fitting the NO₂ Trend

- We fit the low-pass filtered NO₂ first derivative to differentiate between the time periods

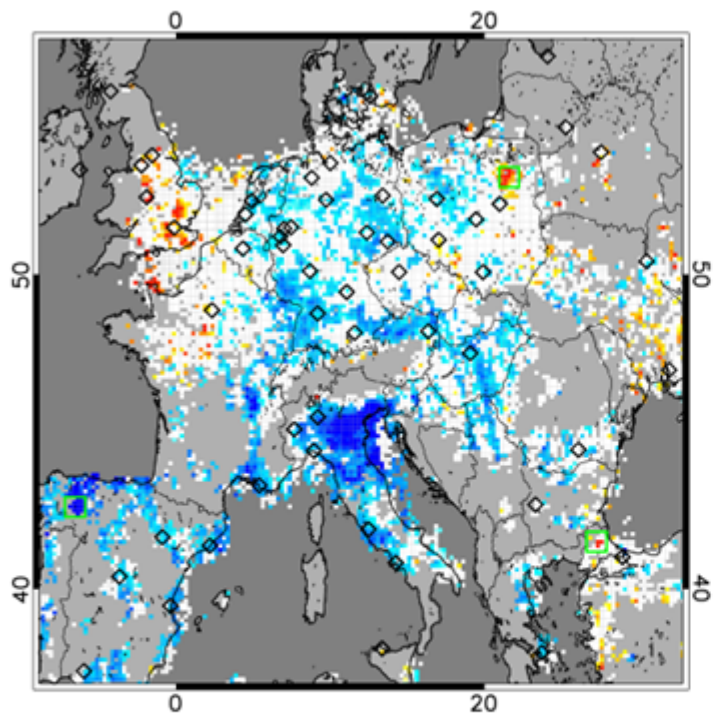
$$\frac{dn_{103,6}}{dt} = \begin{cases} c_{\text{continuous}} & t \notin \text{recession} \\ c_{\text{continuous}} + c_{\text{recession}} & t \in \text{recession} \end{cases}$$

Recession: where the NO₂ first derivative is at a minimum after 2008

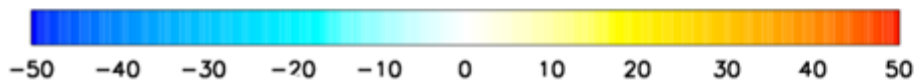


Fitting the NO₂ Trend: Results

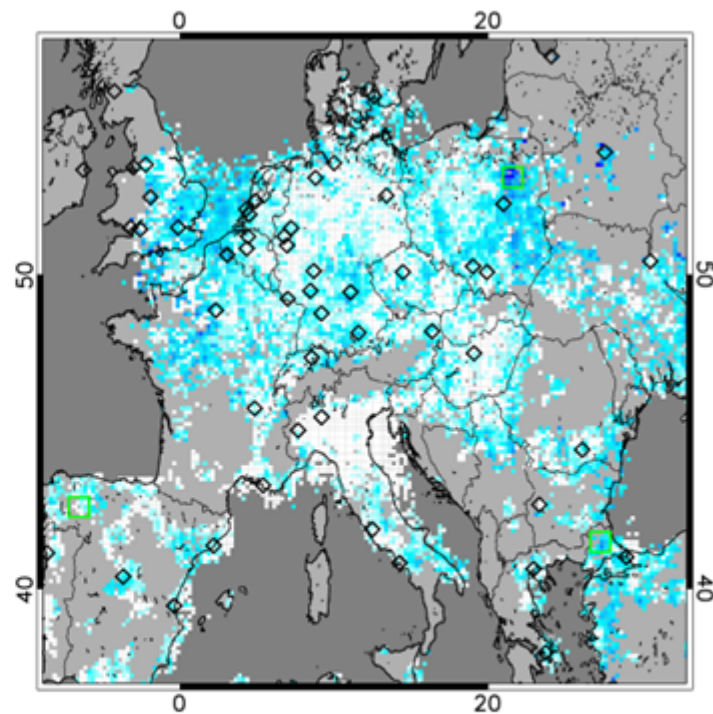
Continuous



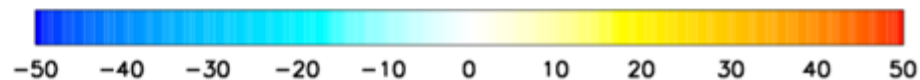
2004–2010 business-as-usual NO₂ concentration changes [%]



Recession

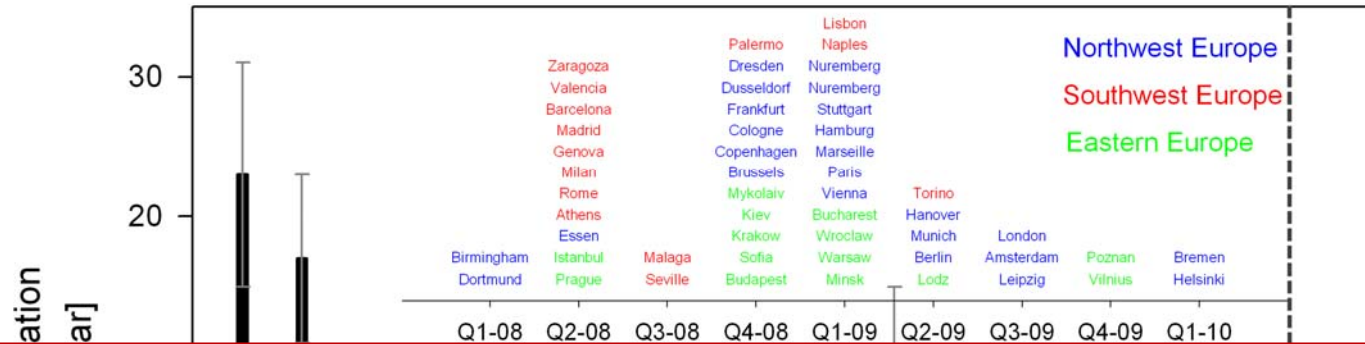


One-year recession NO₂ concentration changes [%]

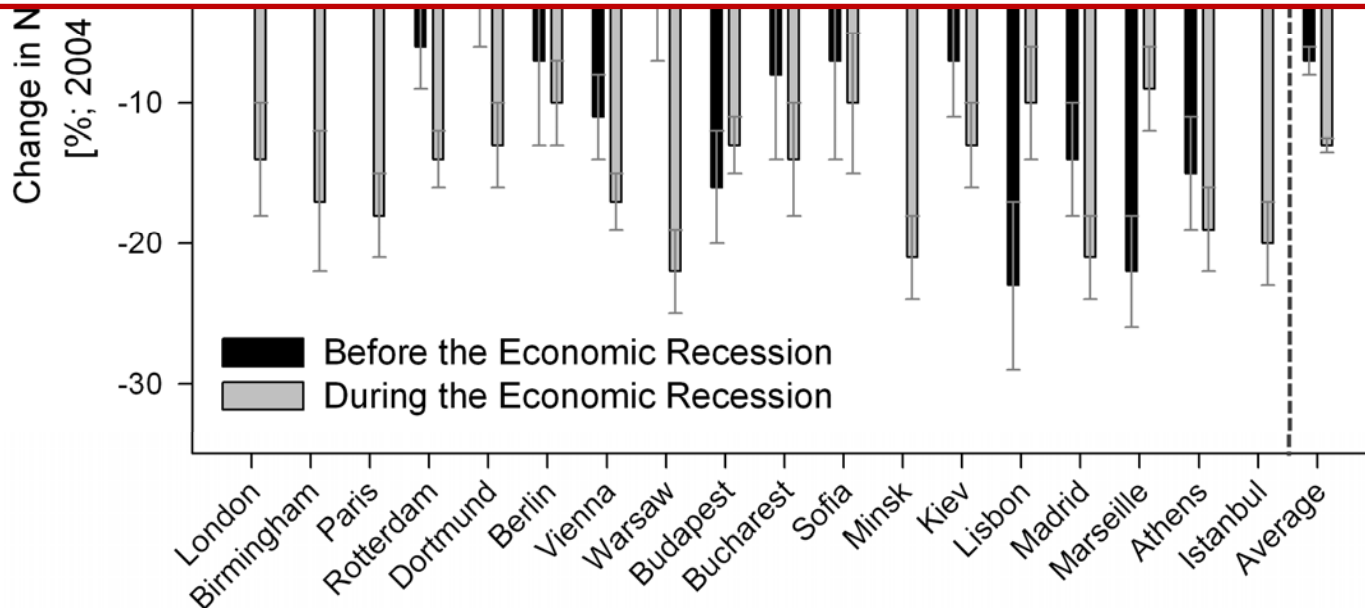




Fitting the NO₂ Trend: Results



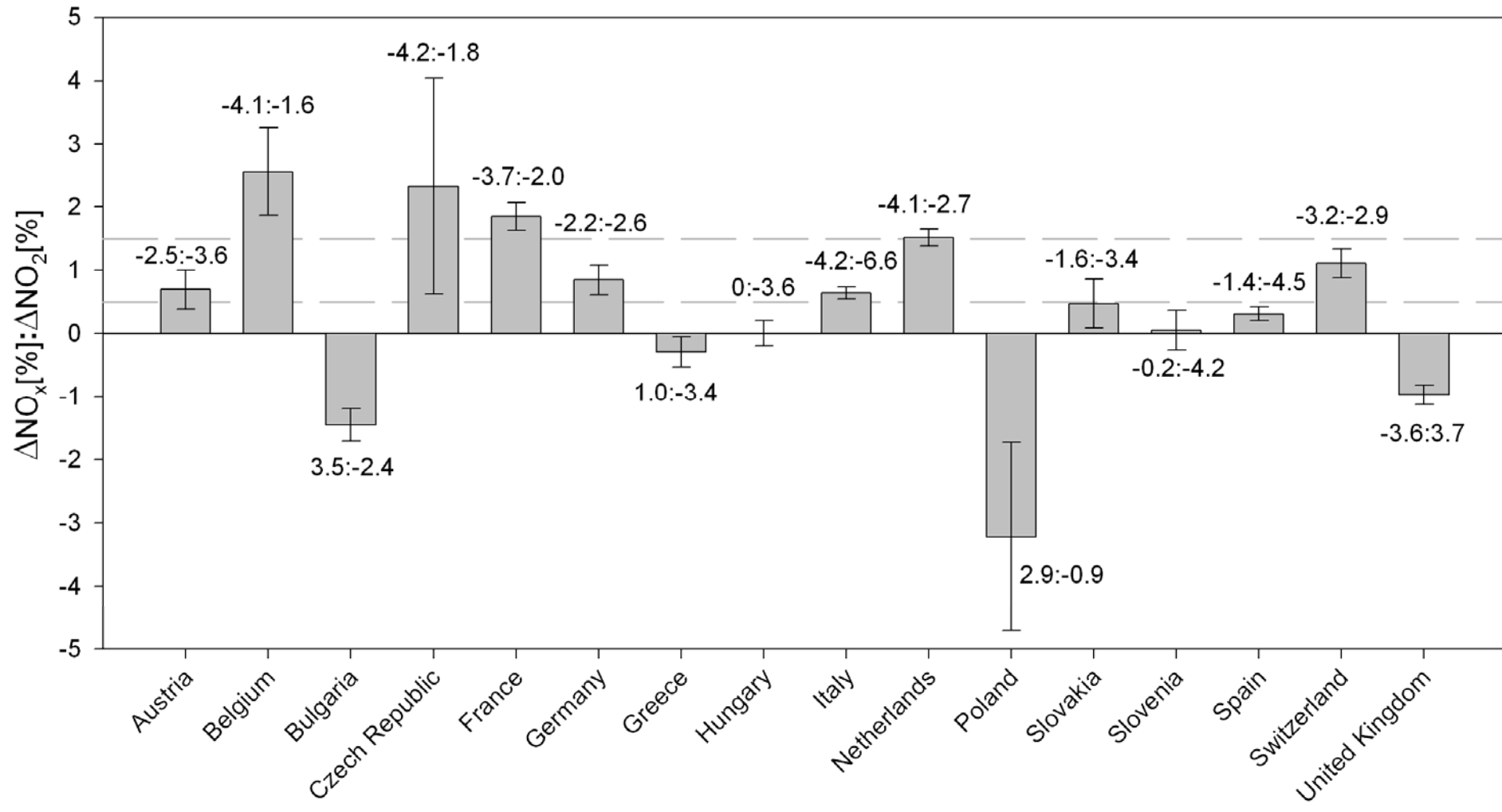
One year of economic recession outweighed
~4-years policy improvements





Fitting the NO₂ Trend: Results

NO_x emissions trend vs Continuous trend





Final Remarks

- High resolution daily OMI observations allow us to analyze spatially AND temporally heterogeneous trends
- The air we breathe today is 10-50% cleaner than in 2004!
- Recession driven fast declines in NO_x emissions → 15-30% declines in NO₂

European NO₂ column trends in the literature

	Trend [% per year]	Time Period
Richter <i>et al.</i> [2005]	-3% to -4%	1996-2004
van der A <i>et al.</i> [2008]	-2% to -5% (mostly insignificant)	1996-2006
Konovalov <i>et al.</i> [2008]	-2% to -5%	1996-2005
Castellanos & Boersma [2011]	-2% to -5% -15 to -30%	2004-2008 2008-2009