On the usefulness of air-quality models in epidemiological health studies

Myrto Valari[1], Laurent Menut[2] and Edouard Chatignoux[3]

[1]NRC Post Doc at the US Environmental Protection Agency
[2]Labortoire de Météorologie Dynamique / IPSL
[3]Observatoire Régional de Santé Île-de-France

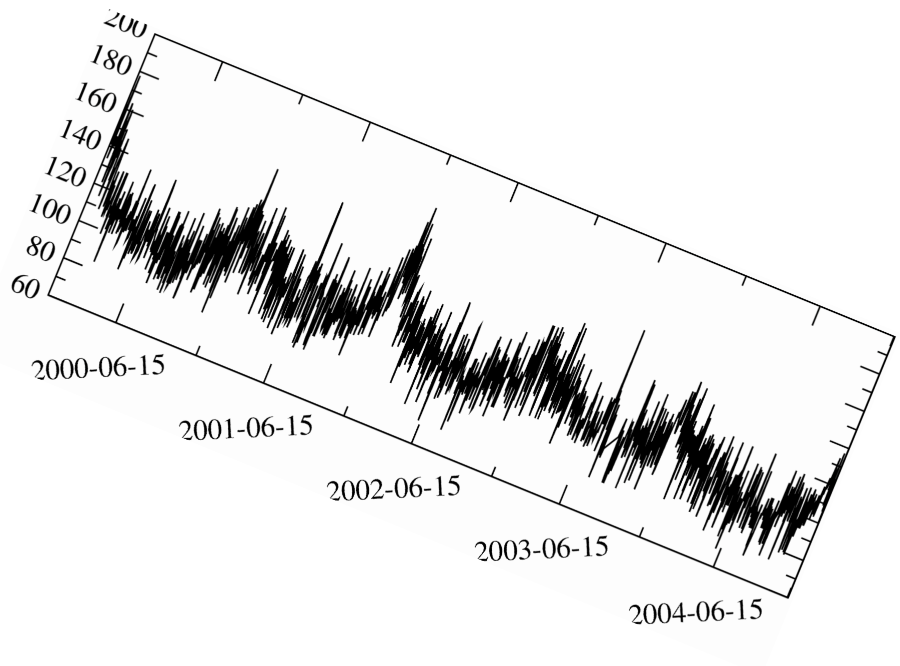
APHEIS network: multi-year, multi-city project on short-term health effects of air-pollution

26 European cities in 12 countries

http://www.aphekom.org

Time series epidemiological model (GAM)

$$log\ \mu_t = \beta_0 + \phi(U_{t-n}) + \alpha Z^T_{t-m} + \boldsymbol{\beta} X_{t-l}$$



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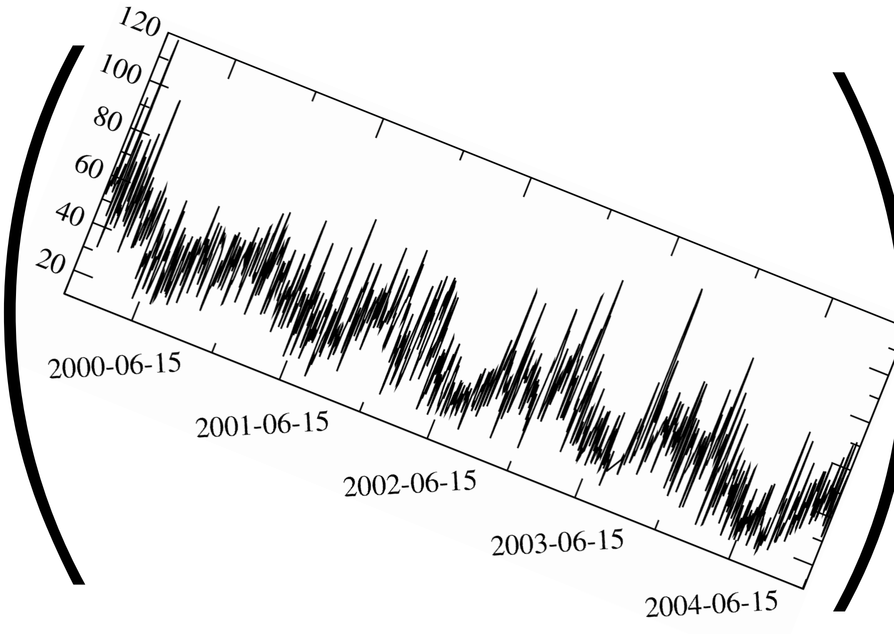


daily mortality counts

day averaged pollutant levels

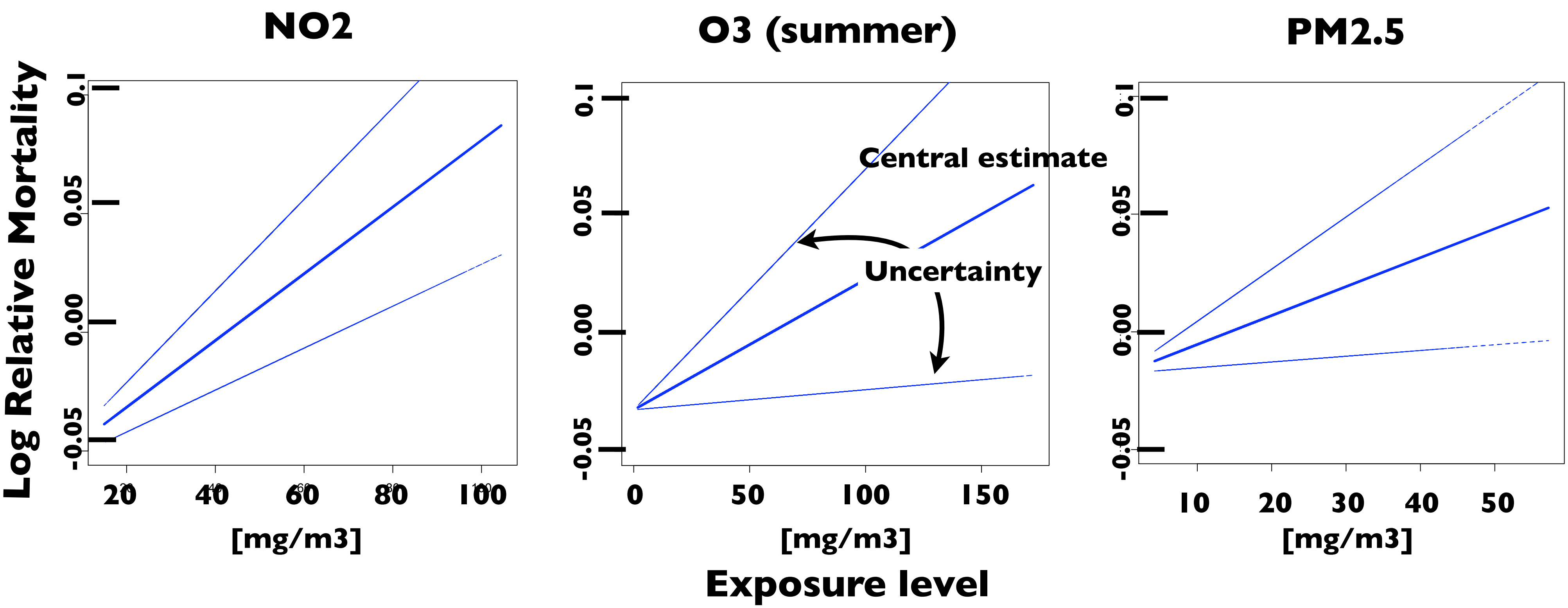
NO_2, O_3, $PM_{2.5}$ vs.mortality

Paris, 2000-2005

Results of the **single-pollutant model**

NO2		O3 (summer)		PM2.5	
ERR (%)	**95% CI**	**ERR (%)**	**95% CI**	**ERR (%)**	**95% CI**
1.4	[0.9; 1.9]	0.6	[0.1; 1.]	1.2	[0.2; 2.2]

ERR: % increase in mortality due to an increase by 10 µg/m3 in the level of exposure
95%: CI 95% probability confidence interval

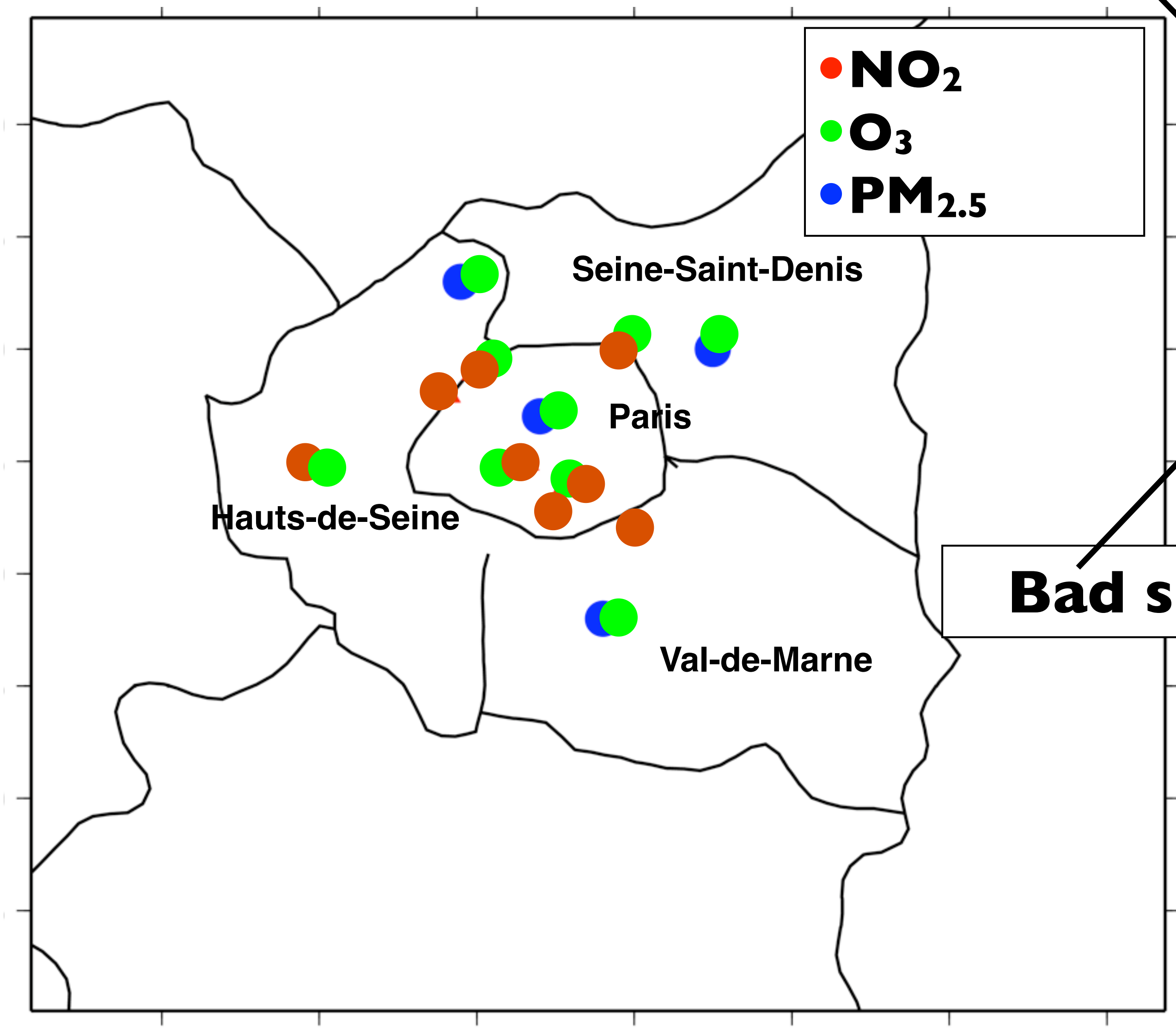


Central-site approach for exposure surrogates

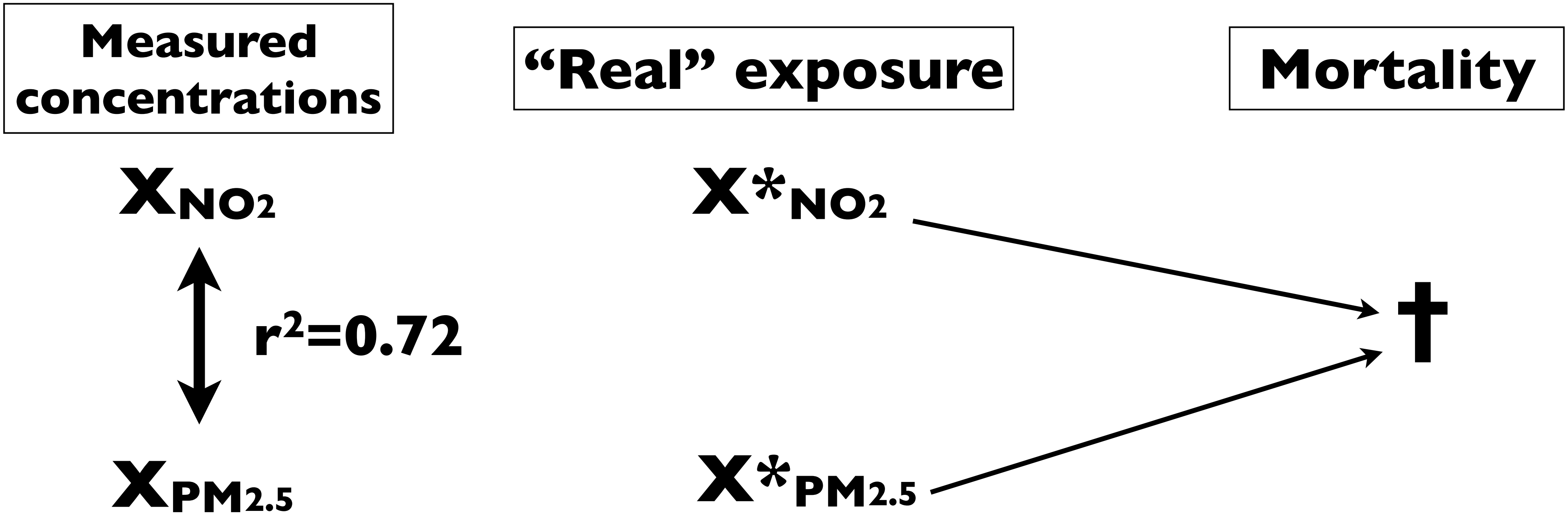
$$X_t = \frac{1}{N}\sum_{i=1}^{N}\overline{C_i}$$

Good spatial representation

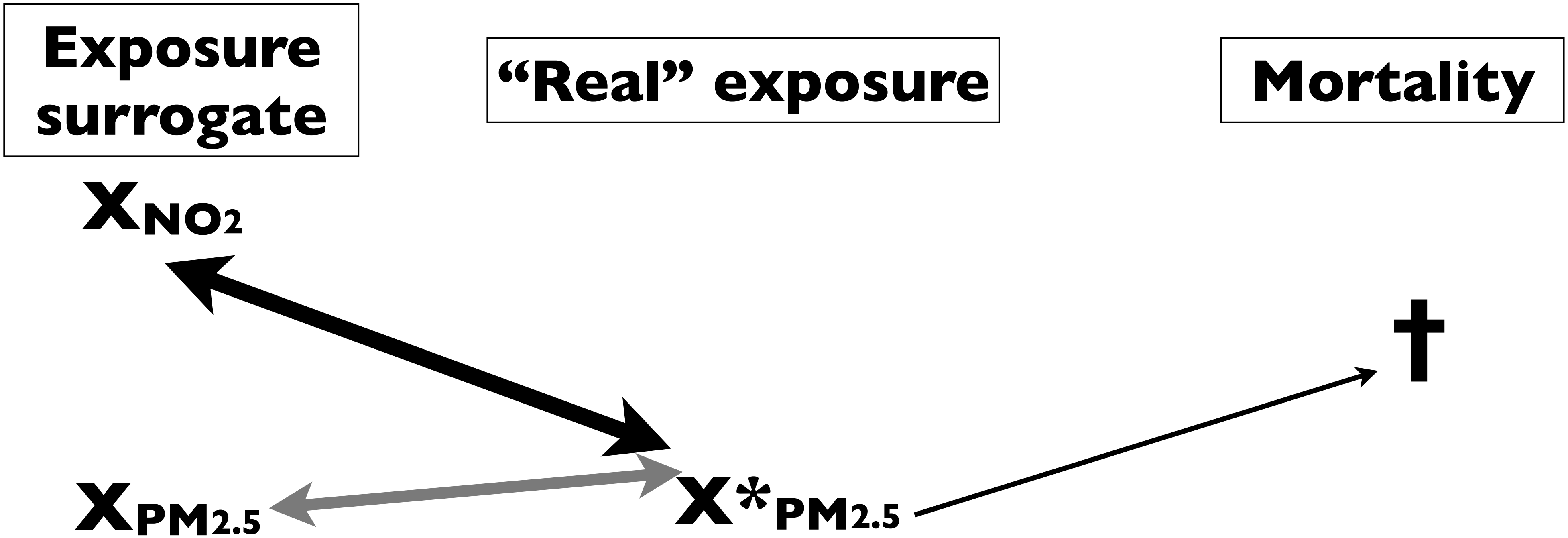
Pollutant	Min	Max
NO2	11	17
O3	8	11
PM2.5	1	4



Bad spatial representation

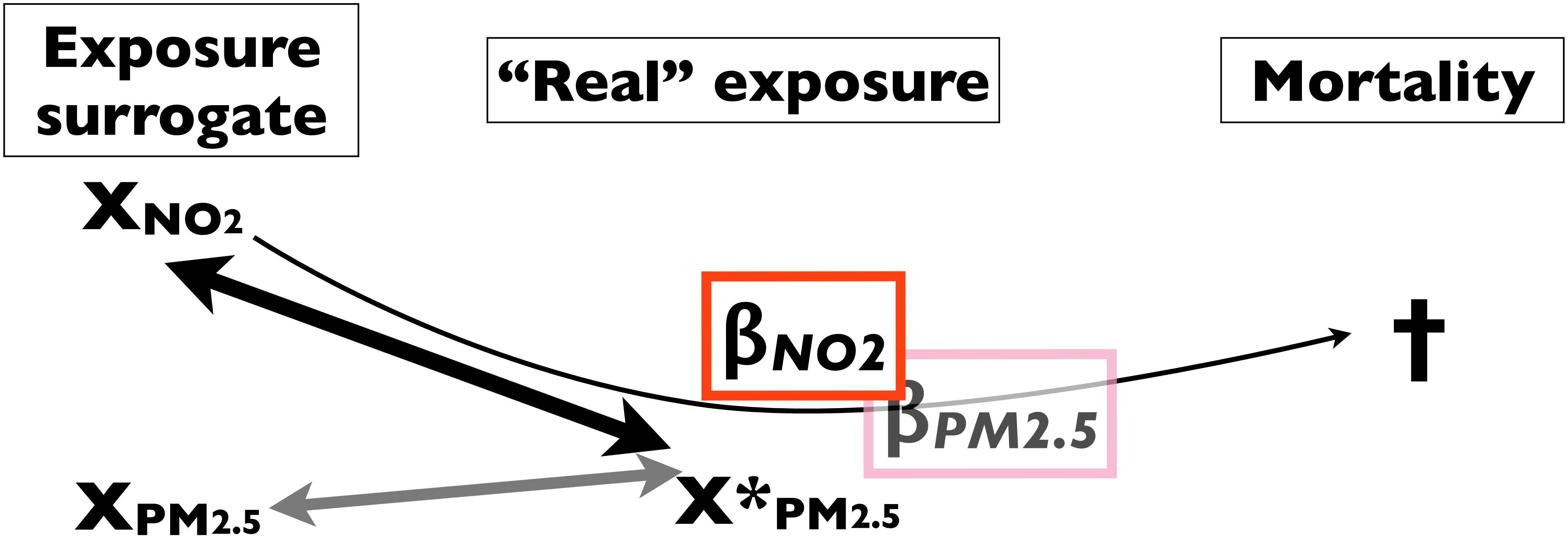


strong correlation between co-pollutants



if $r^2(X_{NO_2}, X^*_{PM2.5}) > r^2(X_{PM2.5}, X^*_{PM2.5})$ then

- **impossible to separate health-effects**



- $PM_{2.5}$ health effect is masked by NO_2
- impossible to separate health-effects

Multi-pollutant regression

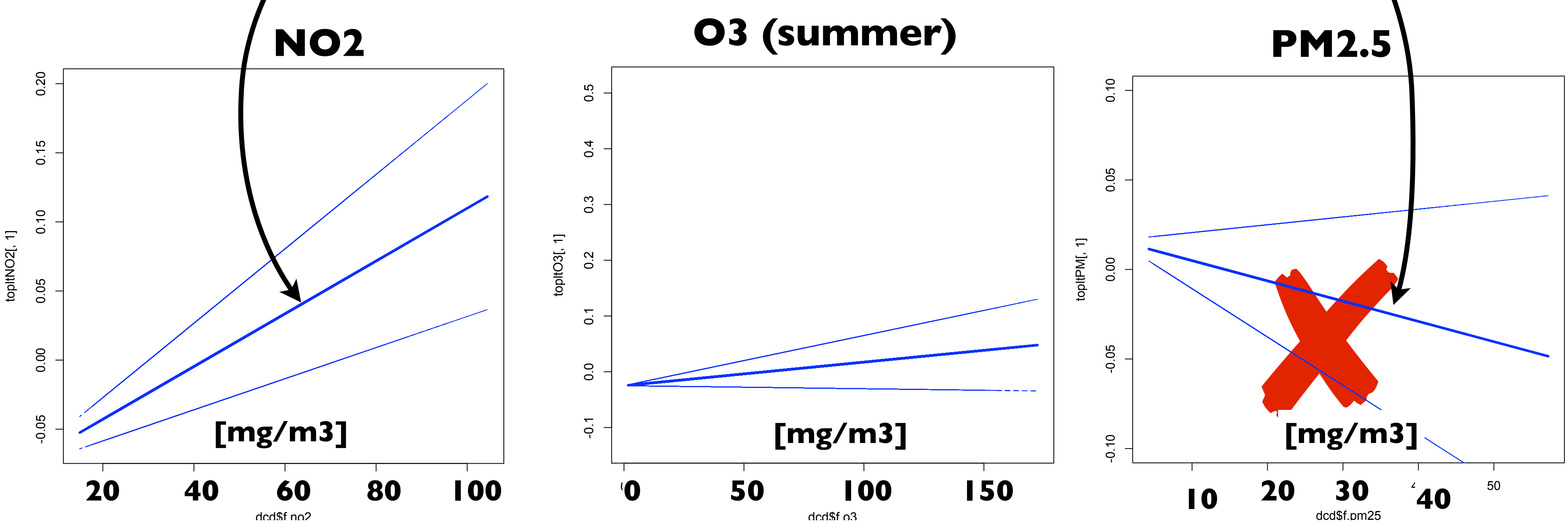
$$log\ \mu_t = ... + \beta_{NO2}[NO2]_{t-l} + \beta_{O3}[O3]_{t-l} + \beta_{PM2.5}[PM2.5]_{t-l}$$

	NO2		O3 (summer)		PM2.5	
	ERR (%)	95% CI	ERR (%)	95% CI	ERR (%)	95% CI
single-pollutant	1.4	[0.9; 1.9]	0.6	[0.1; 1.]	1.2	[0.2; 2.2]
multi-pollutant	1.9	[1.1; 2.7]	0.4	[0.0; 0. 9]	-1.1	[-2.6; 0.5]

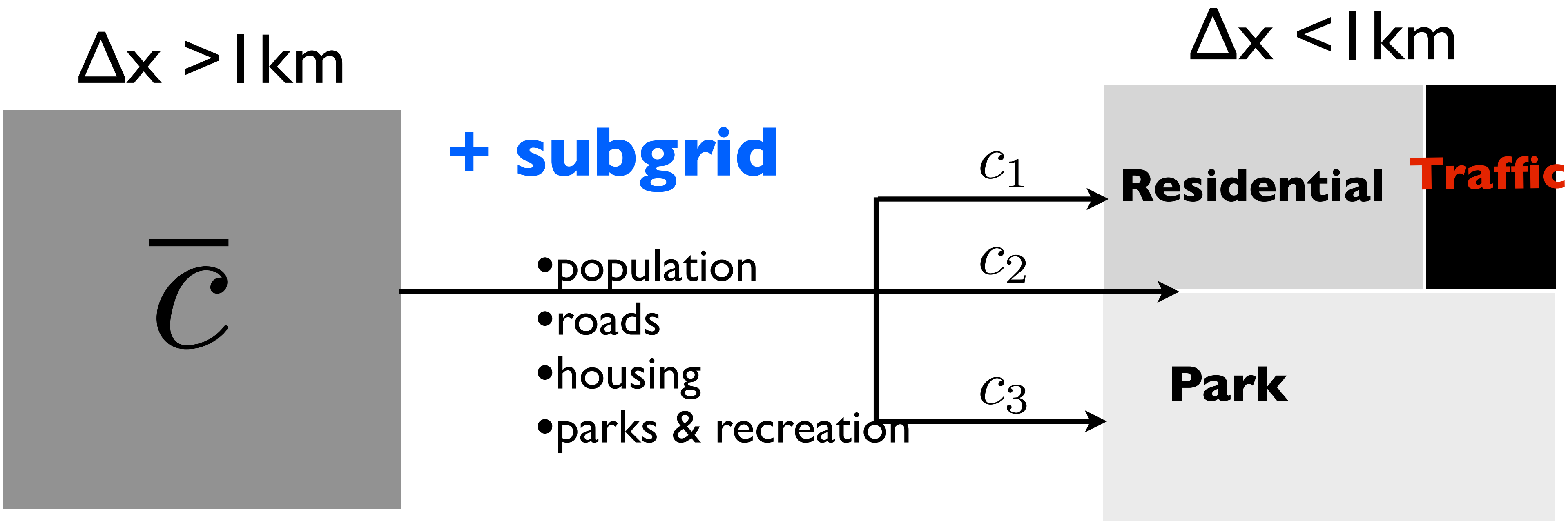
too big

too small

NO2 absorbs the effect of PM



How can chemistry-transport model help?



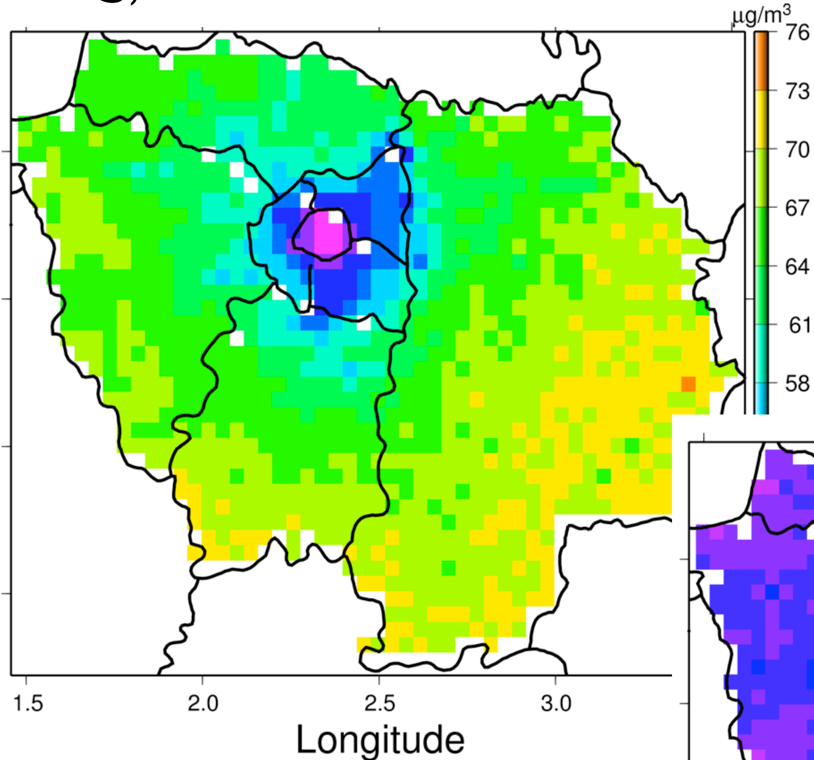
Valari and Menut, *Atmospheric Environment*, **44,** 2010

+ 3 activity regimes

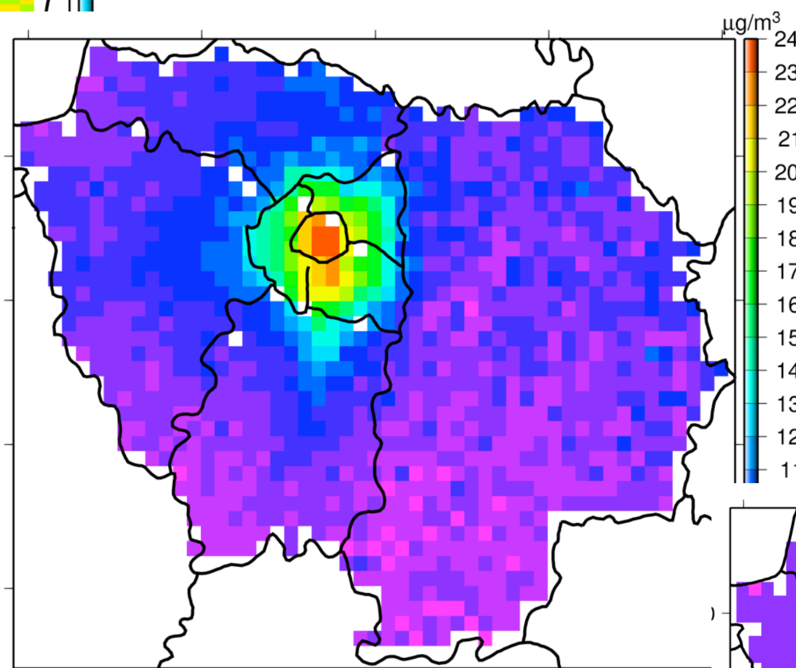
Valari et al., *JAWMA*, 2010 *(in press)*

Daily averaged 'exposure' maps

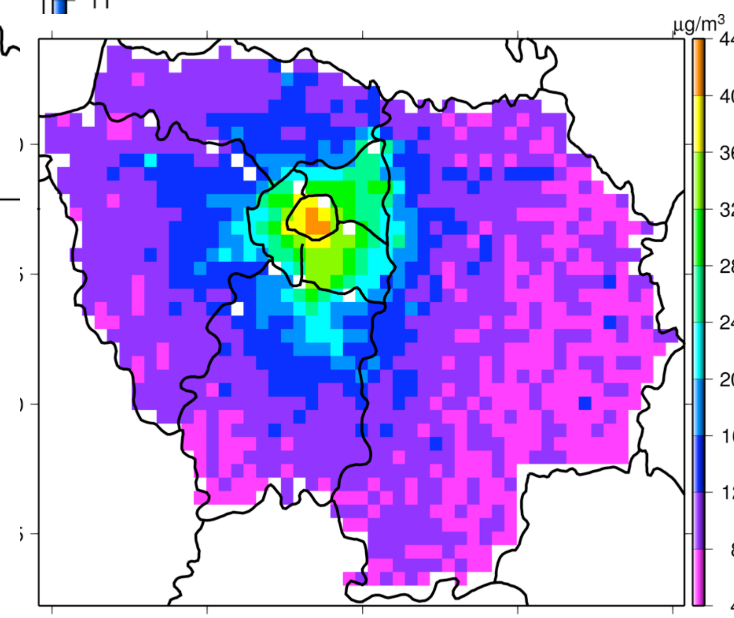
O_3, *2004-07-07*



$PM_{2.5}$, *2004-07-07*



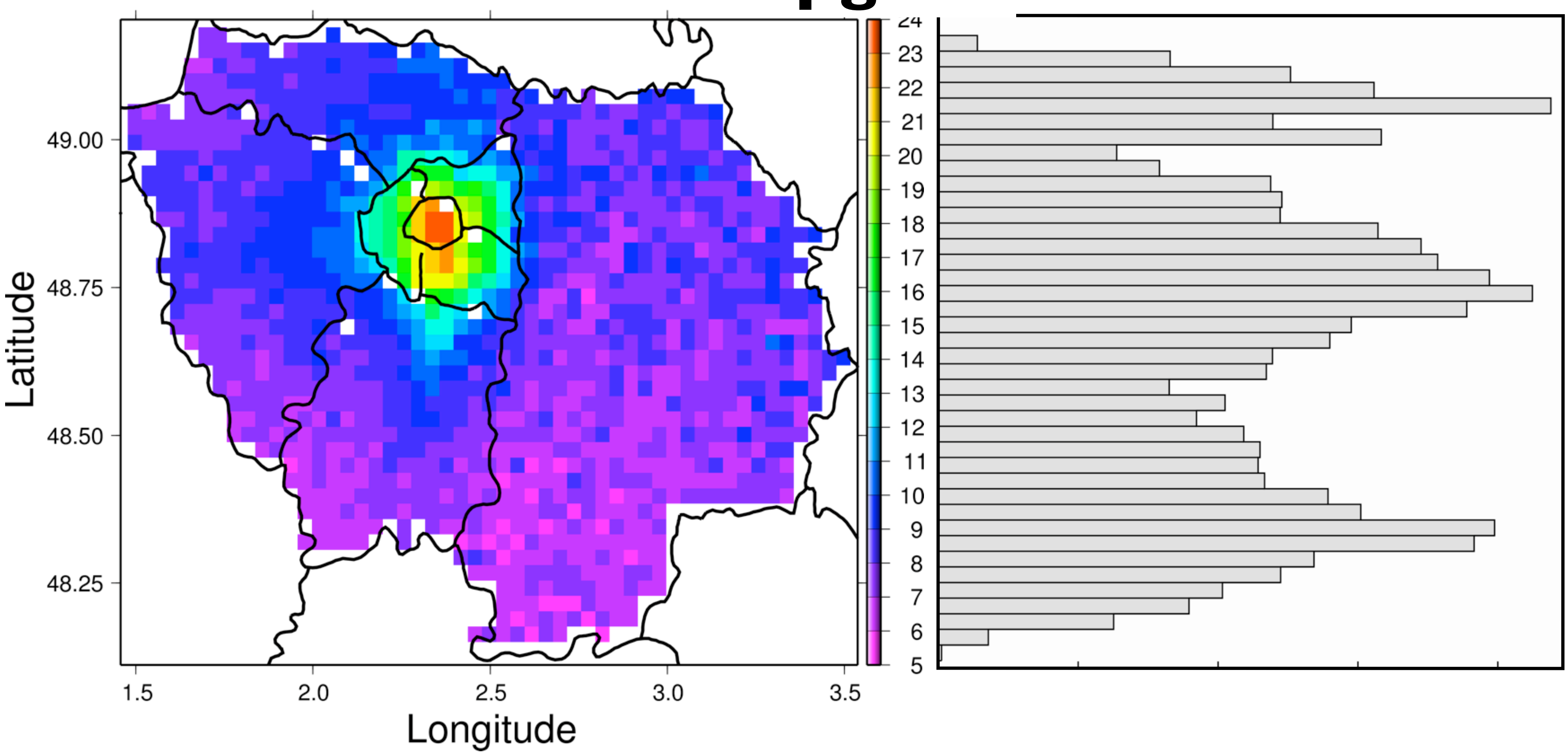
NO_2, *2004-07-07*



Exposure distribution

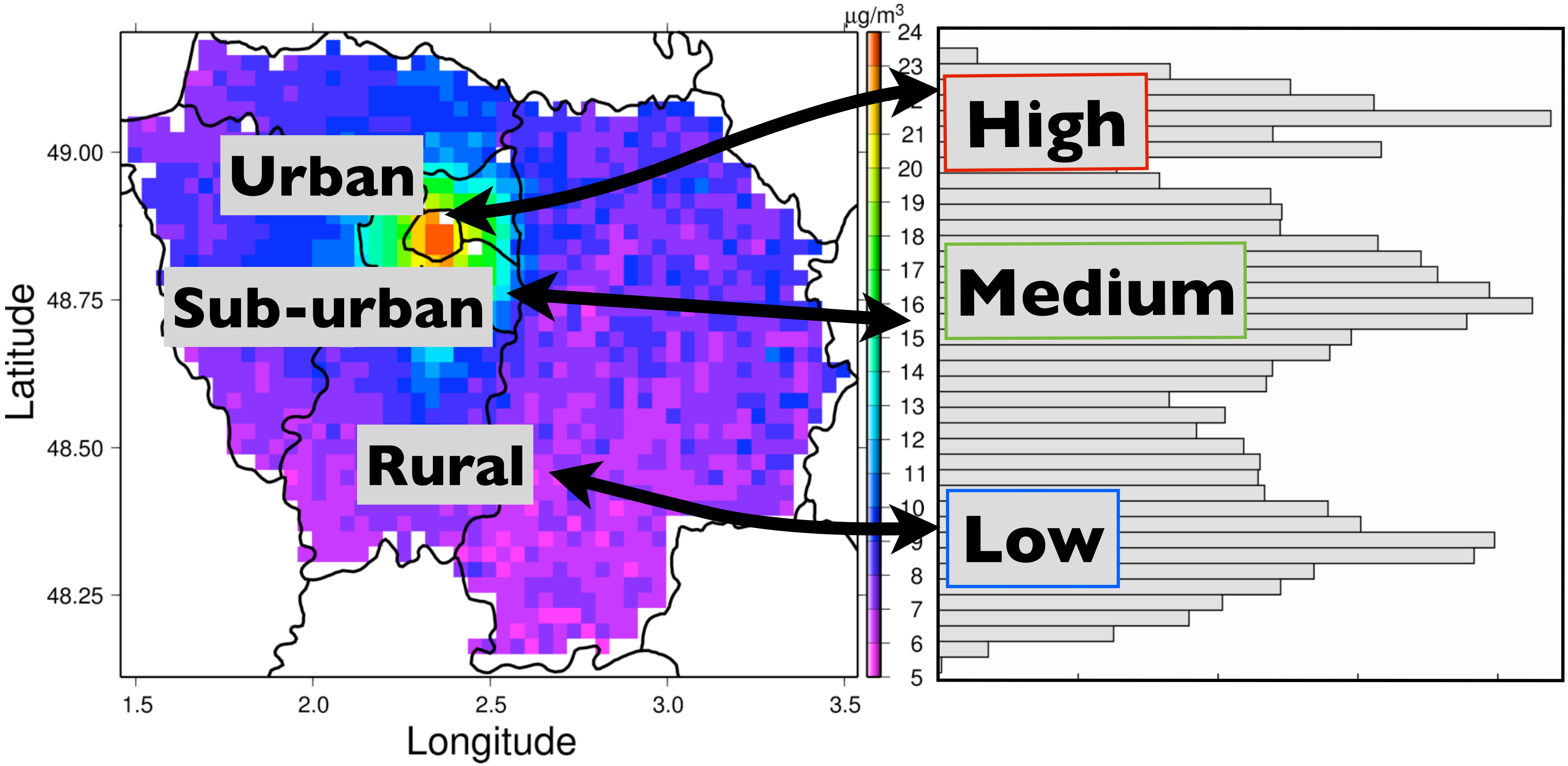
PM$_{2.5}$, *2004-07-07*

µg/m³

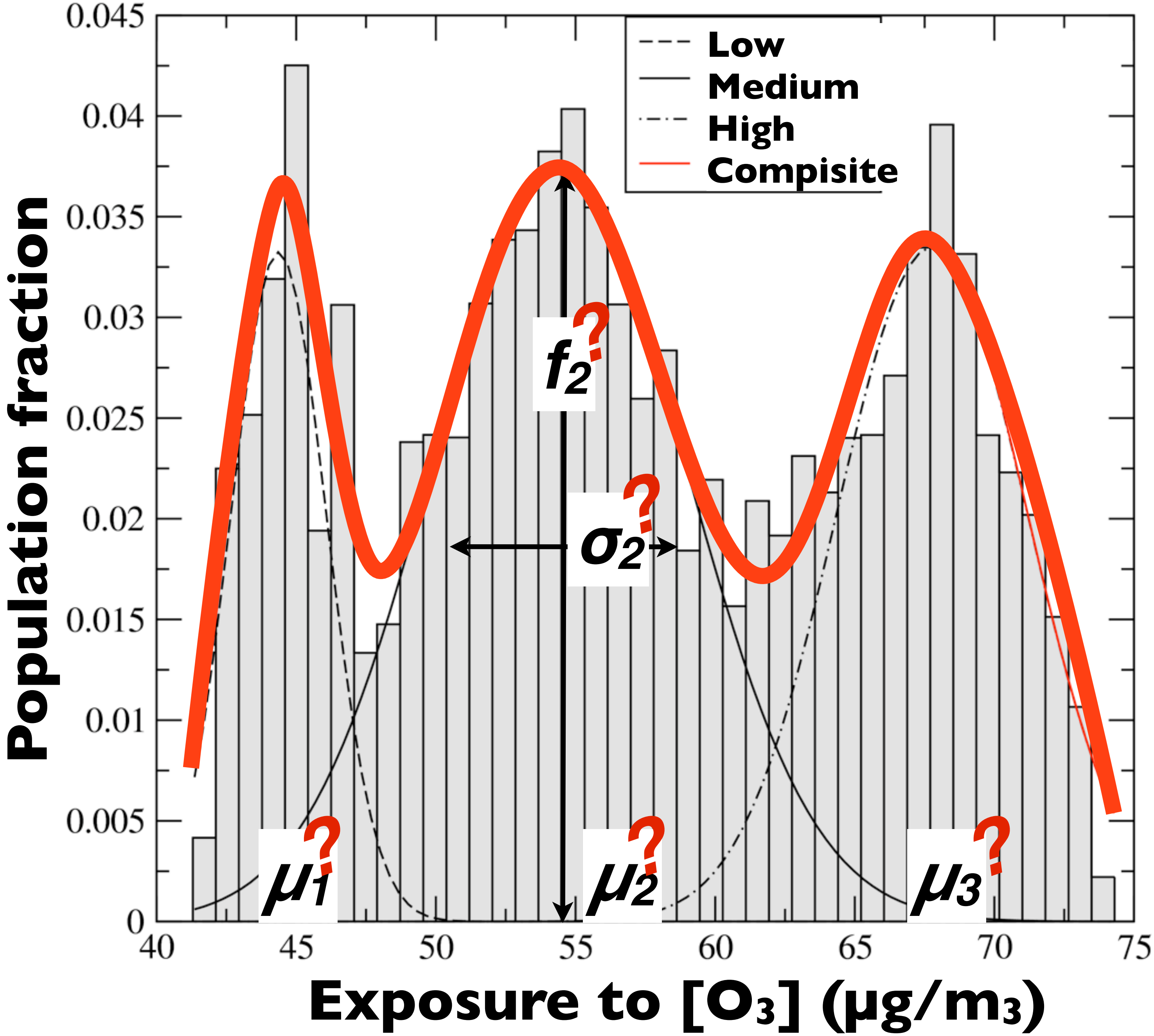


Distribution mode =>Population

PM$_{2.5}$, *2004-07-07*



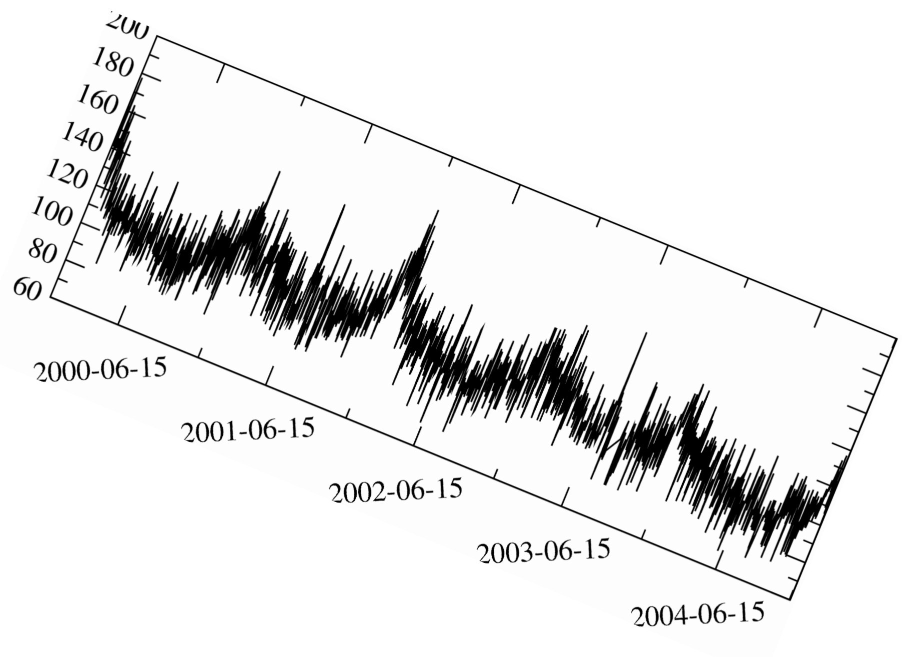
Parametrization: $$D(x) = \sum_{i=1}^{3} \frac{f_i}{\sigma_i \sqrt{2\pi}} \exp\left[-\frac{(x-\mu_i)^2}{2\sigma_i^2}\right]$$



Sensitivity study

$$log\ \mu_t = \beta_0 + \phi(U_{t-n}) + \alpha Z_{t-m}^T + \boldsymbol{\beta} X_{t-l}$$

?



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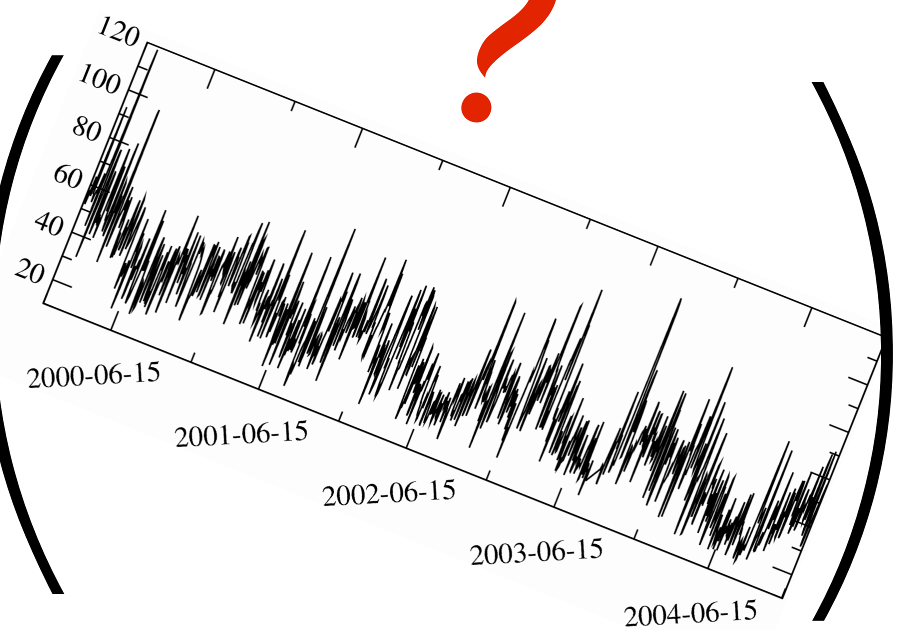


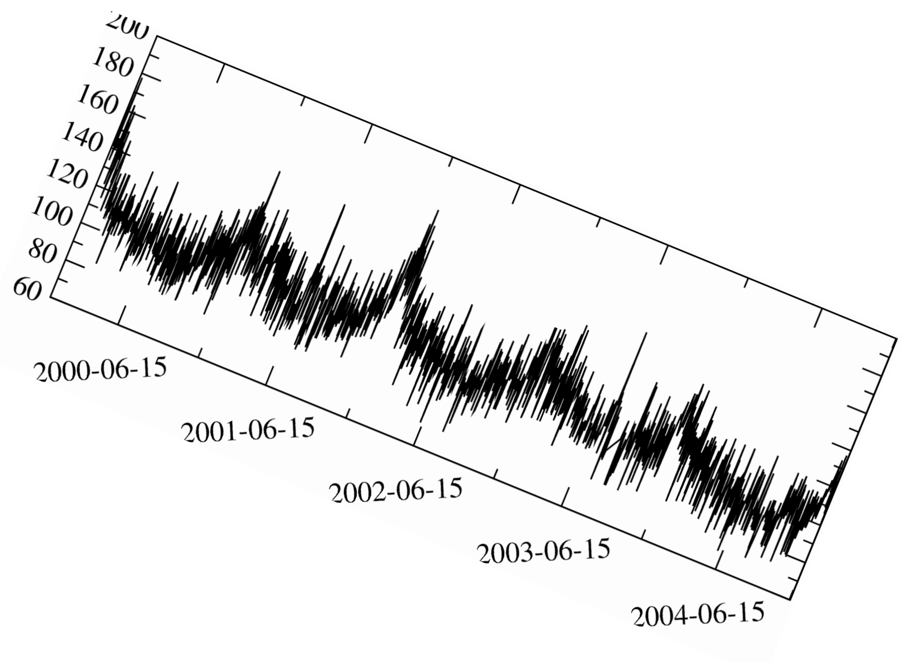
daily mortality counts

day averaged pollutant levels

Sensitivity study

$$log\ \mu_t = \beta_0 + \phi(U_{t-n}) + \alpha Z^T_{t-m} + \boldsymbol{\beta} X_{t-l}$$

I) Monitors



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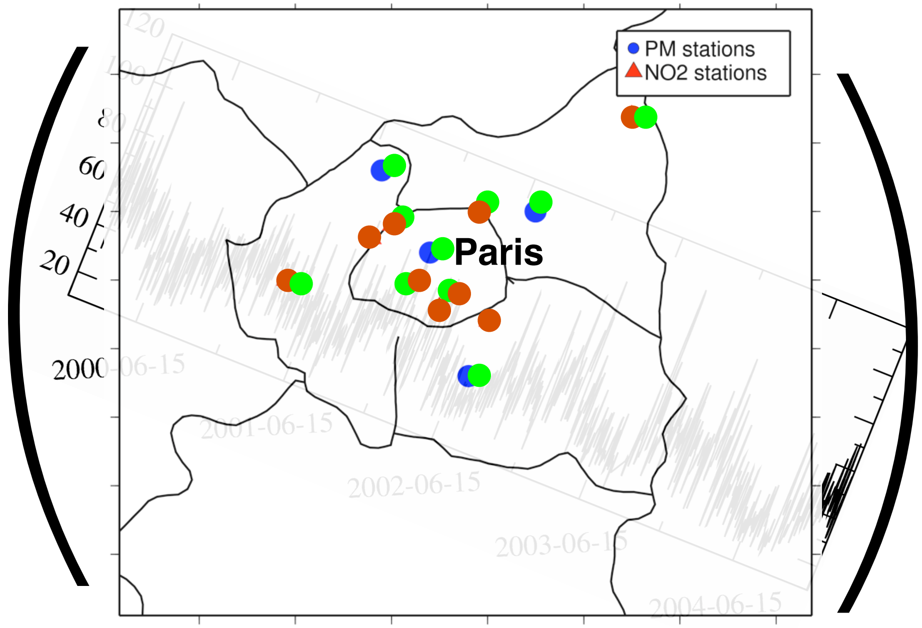

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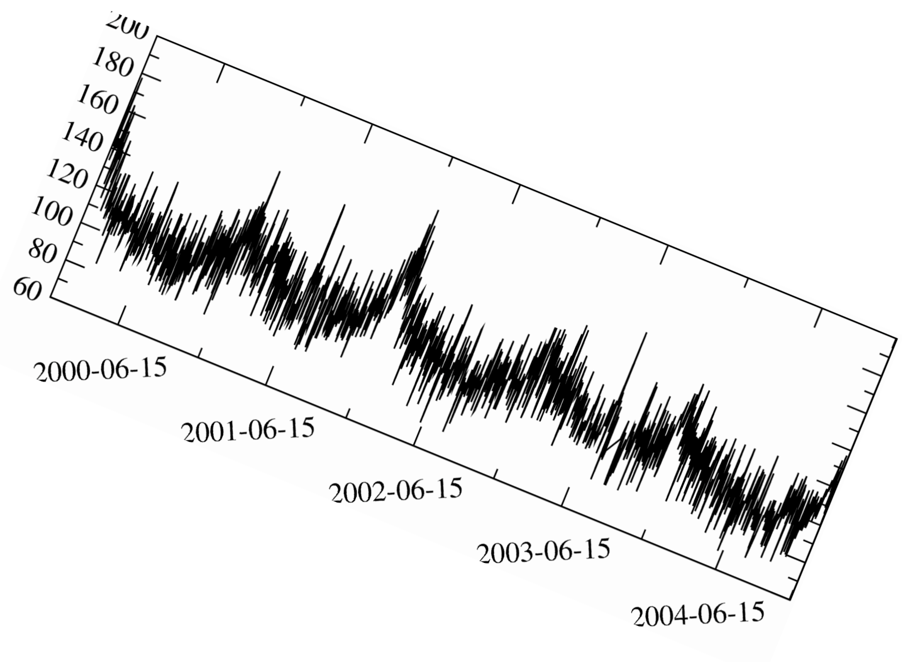
Sensitivity study

$$log\ \mu_t = \beta_0 + \phi(U_{t-n}) + \alpha Z_{t-m}^T + \beta X_{t-l}$$

2) CTM at 3km



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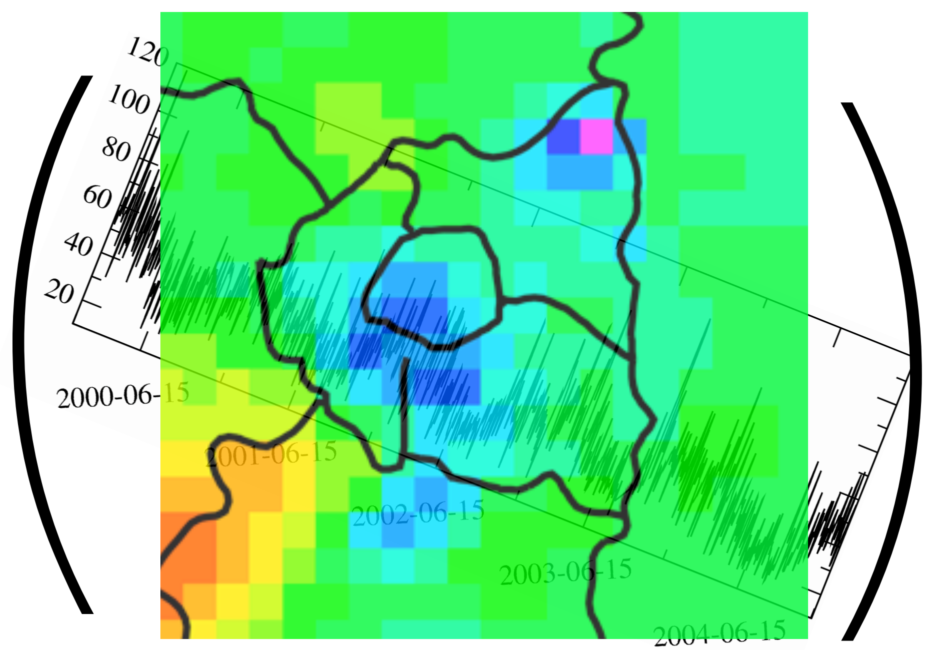

daily mortality counts

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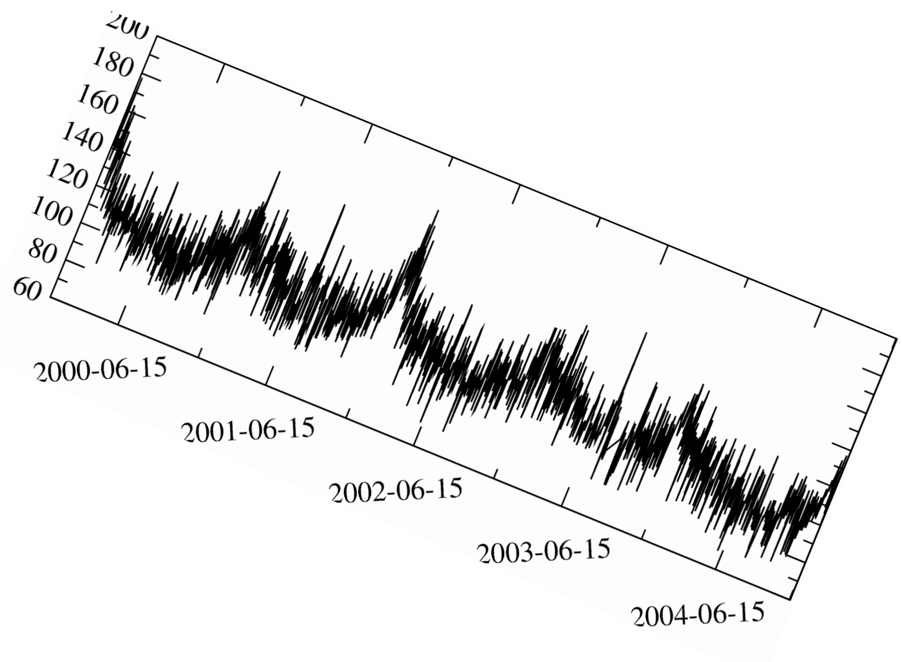
Sensitivity study

$$log\ \mu_t = \beta_0 + \phi(U_{t-n}) + \alpha Z^T_{t-m} + \boldsymbol{\beta}\, X_{t-l}$$

3) CTM+Subgrid+Activity



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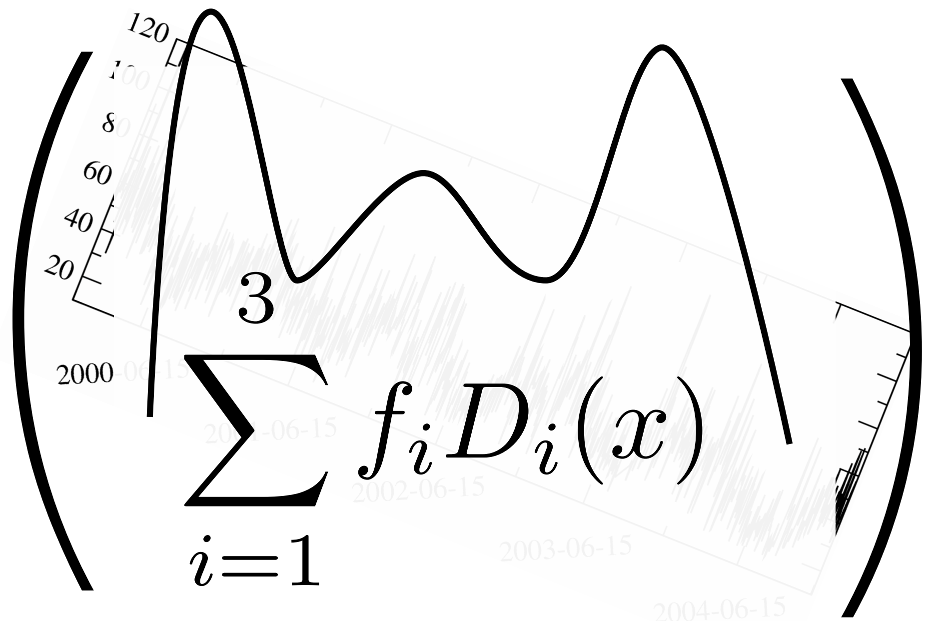
$$\left(\sum_{i=1}^{3} f_i D_i(x) \right)$$



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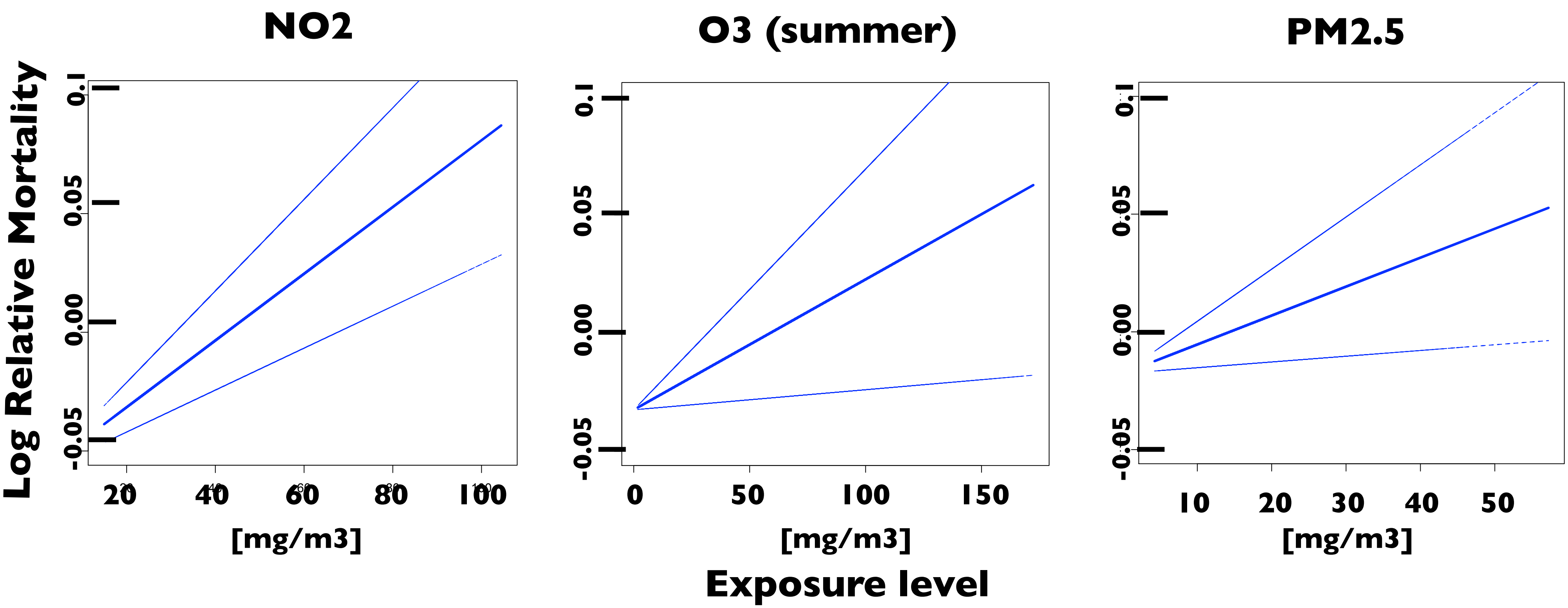
single-pollutant	NO2		O3 (summer)		PM2.5	
	ERR (%)	95% CI	ERR (%)	95% CI	ERR (%)	95% CI
MONITOR	1.4	[0.9; 1.9]	0.6	[0.1; 1.]	1.2	[0.2; 2.2]
CTM						
ACTIVITY						



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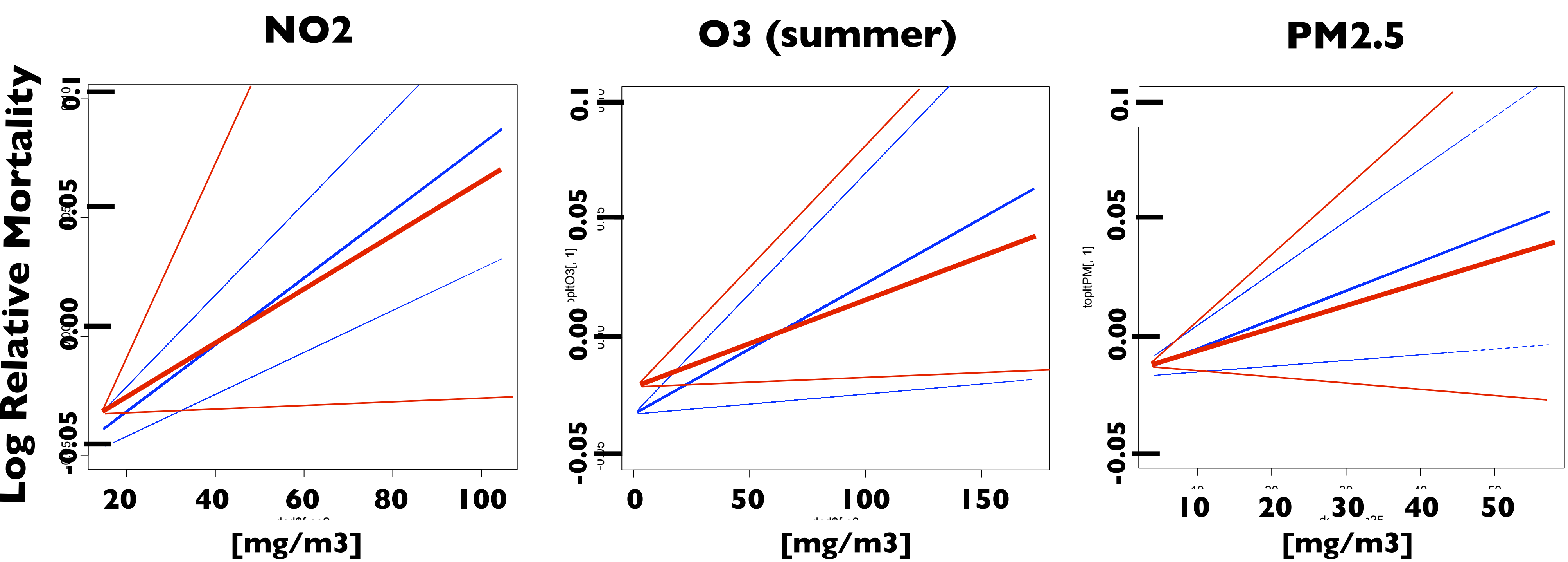
MONITOR	1.4	[0.9; 1.9]	0.6	[0.1; 1.]	1.2	[0.2; 2.2]
CTM	1.1	[0.0; 2.3]	0.4	[0.0; 0.9]	0.9	[-0.5; 2.3]
ACTIVITY						

- **Lower central estimates**
- **Larger uncertainty**
- **but... small differences**



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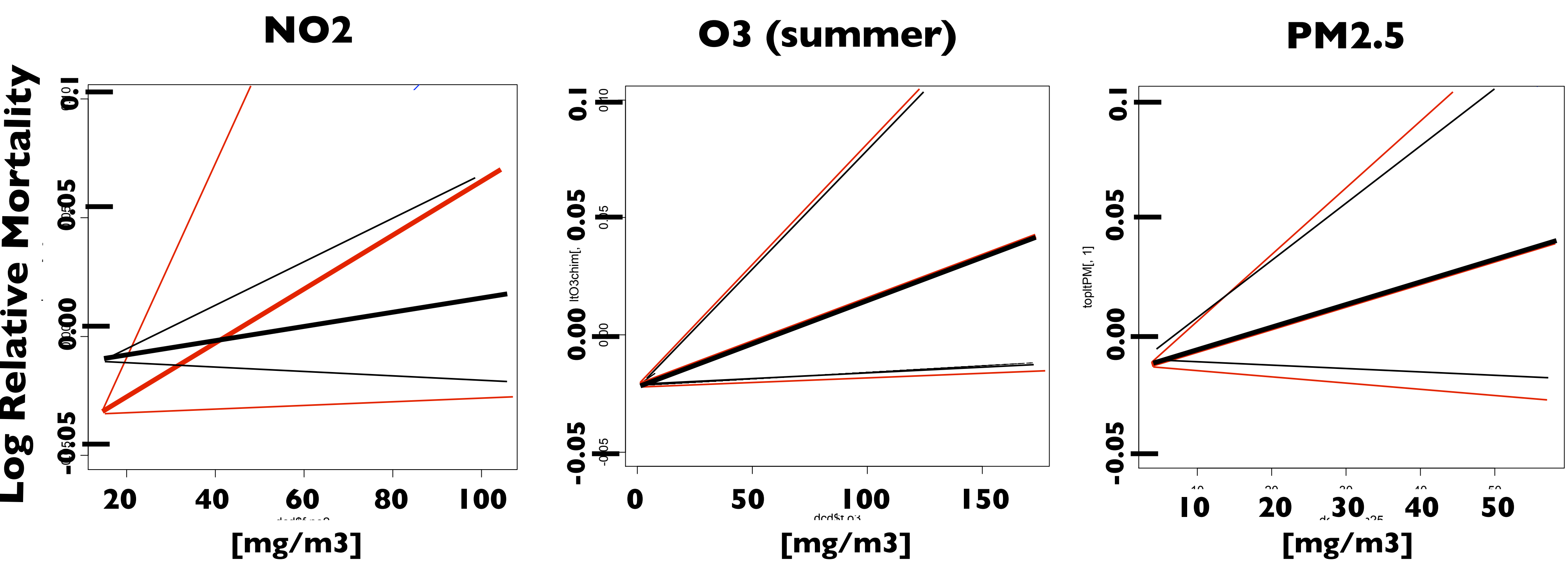
CTM	1.1	[0.0; 2.3]	0.4	[0.0; 0.9]	0.9	[-0.5; 2.3]
ACTIVITY	0.3	[-0.4 ; 1.0]	0.4	[0.0 ; 0.8]	0.9	[-0.2 ; 2.0]

Similar results
Smaller uncertainties



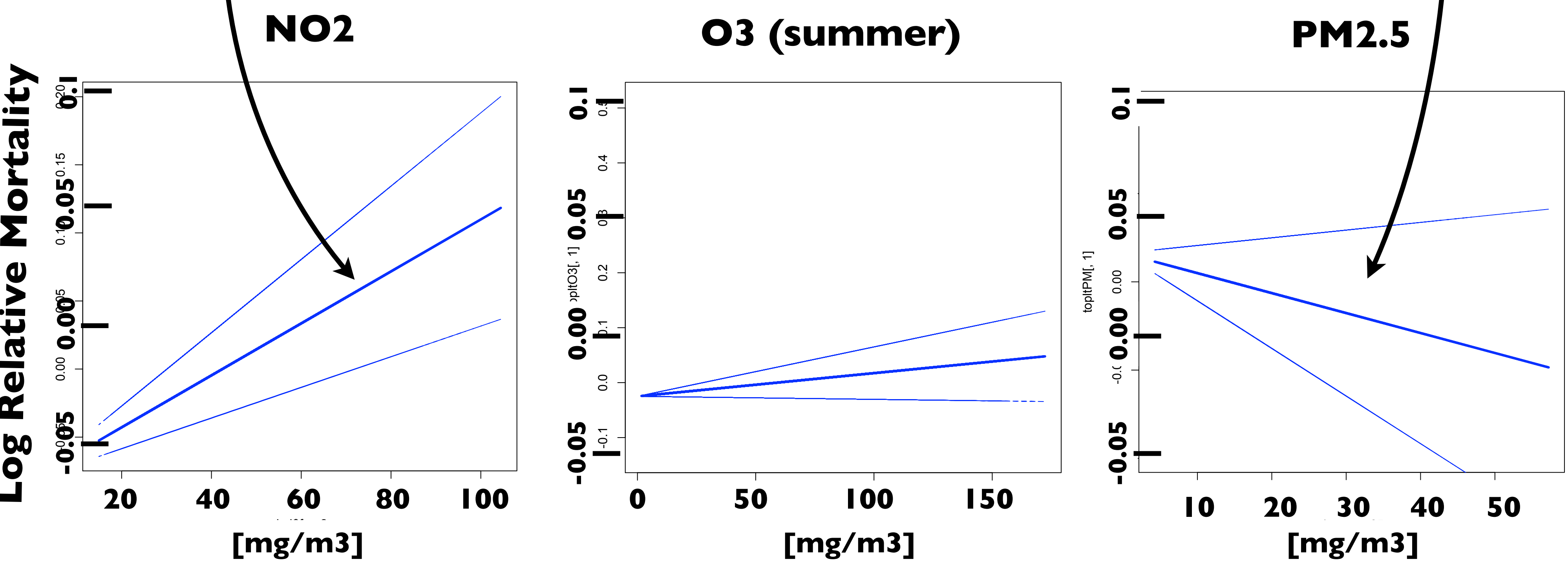
multi-pollutant

	NO2		O3 (summer)		PM2.5	
	ERR (%)	95% CI	ERR (%)	95% CI	ERR (%)	95% CI
MONITOR	1.9	[1.1; 2.7]	0.4	[0.0; 0. 9]	-1.1	[-2.6; 0.5]
CTM						
ACTIVITY						

too big

too small

NO2 absorbs the effect of PM



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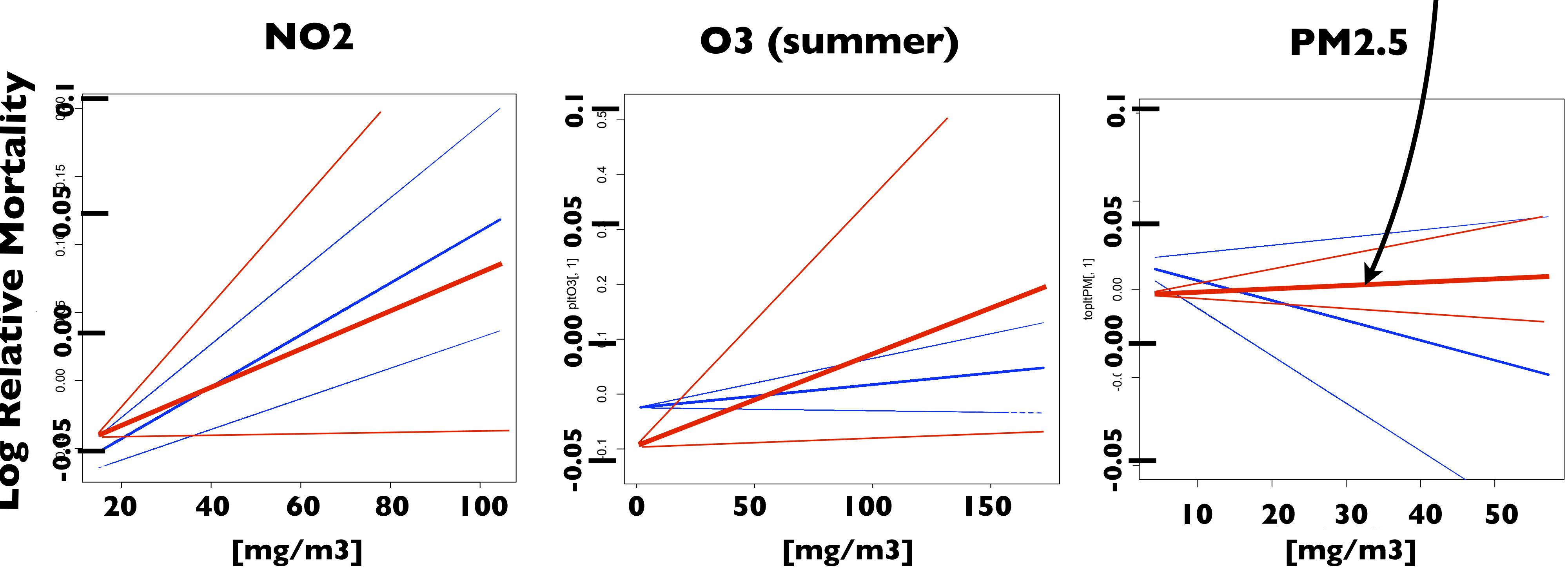
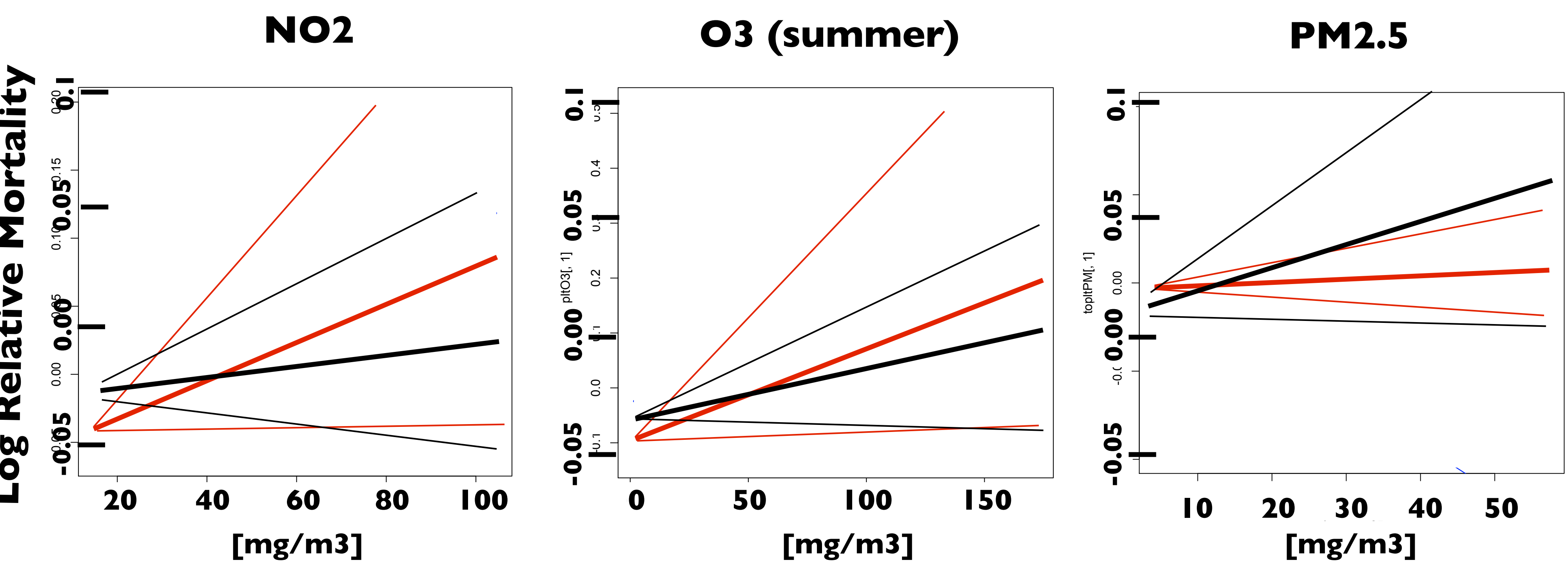
	ERR (%)	95% CI	ERR (%)	95% CI	ERR (%)	95% CI
MONITOR	1.9	[1.1; 2.7]	0.4	[0.0; 0. 9]	-1.1	[-2.6; 0.5]
CTM	1.4 ✗	[-0.3; 3.1]	1.6 ✗	[0.1; 3.1]	0.2 ✗	[-0.5; 1.0]
ACTIVITY						

similar bias for CTM modelled concentrations



multi-pollutant	NO2		O3 (summer)		PM2.5	
	ERR (%)	95% CI	ERR (%)	95% CI	ERR (%)	95% CI
MONITOR	1.9 ✗	[1.1; 2.7]	0.4	[0.0; 0. 9]	-1.1 ✗	[-2.6; 0.5]
CTM	1.4 ✗	[-0.3; 3.1]	1.6 ✗	[0.1; 3.1]	0.2 ✗	[-0.5; 1.0]
ACTIVITY	0.4 ✔	[-0.6 ; 1.4]	0.9 ✔	[-0.4 ; 1.2]	1.3 ✔	[-0.0 ; 2.7]

All estimates are positive when activity data are accounted for



What should be kept in mind?

- Air-quality model provides reasonable effect estimates when used in the same way as monitor data
- Similar problems are encountered when monitor or ‘simple’ CTM concentrations are used in a multi-pollutant health study design
- Only when activity data are accounted for do co-pollutants effects be separated