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Health effects of air pollution mixtures

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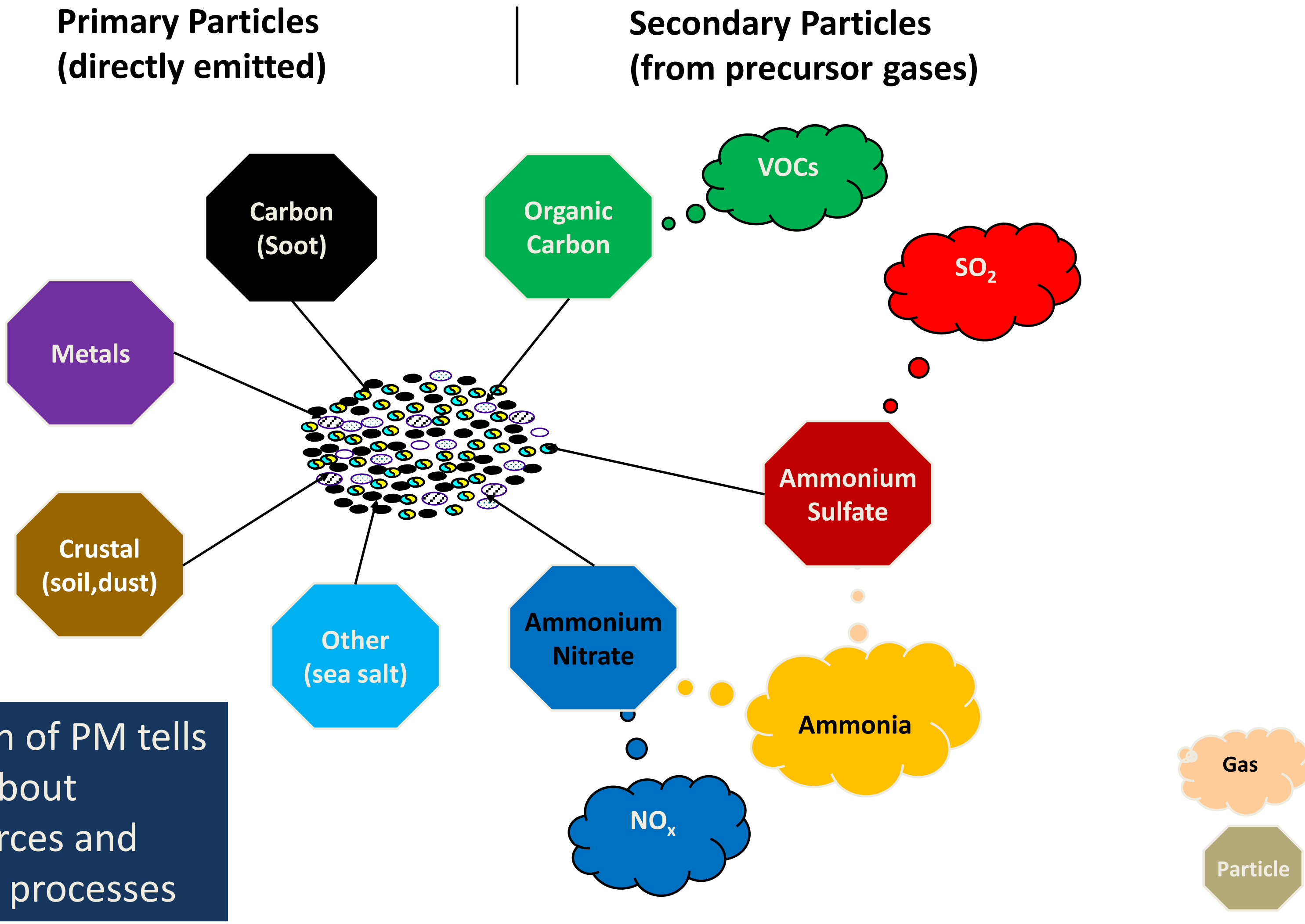
PM10, PM2.5 are complex mixtures



Composition of PM tells us about the sources and formation processes

What's harmful part of the PM mix?

- It is unlikely that all parts of the PM mix are equally harmful.
- Clearly if we knew the smoking gun then we could target our efforts more effectively for public health.
- This might not be the same as optimising policy to decrease PM mass concentration or to decrease all sources in someway.
- Will actions to control NO_2 help the toxic part of PM?

What’s harmful part of the PM mix?

- Some studies point to black carbon or metals or organics or sulphate but the current expert consensus to regulators says:

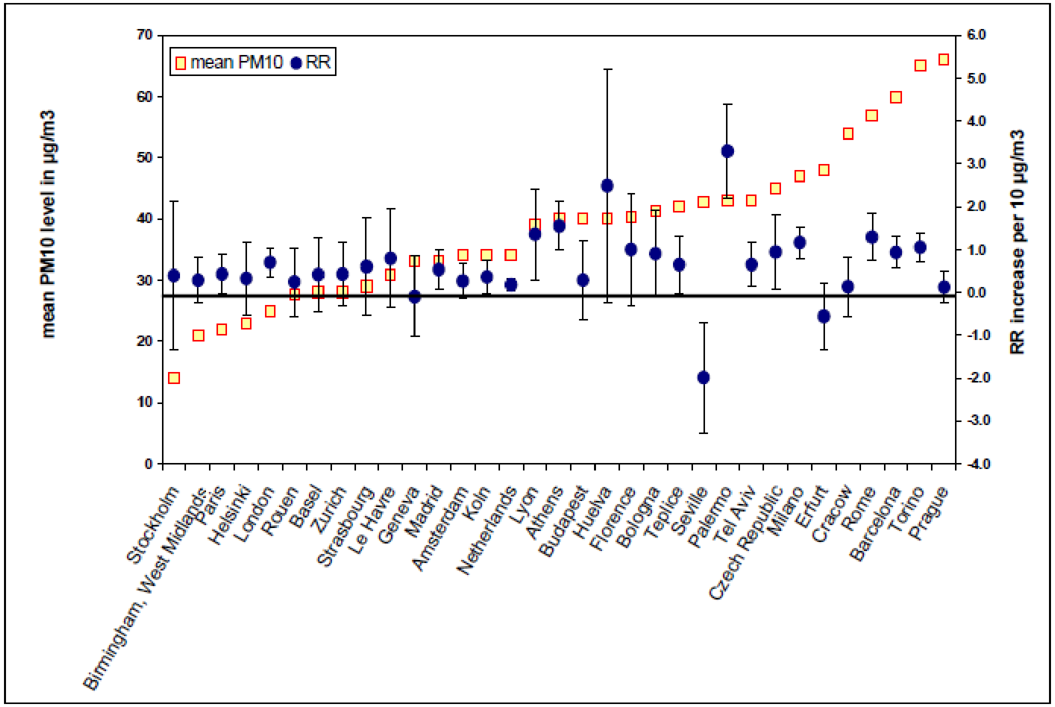
- COMEAP (2015): “…there is <u>insufficient evidence</u> to assess, on the basis of <u>relative toxicity</u>, whether reduction of one component of particulate matter would improve health more than targeting other components.”

- WHO (2013): “.. <u>not sufficient evidence</u> to differentiate those constituents (or sources) that are more closely related to specific health outcomes.”

- HEI: “better <u>understanding of exposure and health effects</u> is needed before it can be concluded that regulations targeting specific sources or components of PM2.5 will protect public health more effectively …”

Time series health studies

- The most common type of air pollution health study.
- Focus on short-term health effects only.
- Use one or small number of background monitoring sites as exposure surrogate



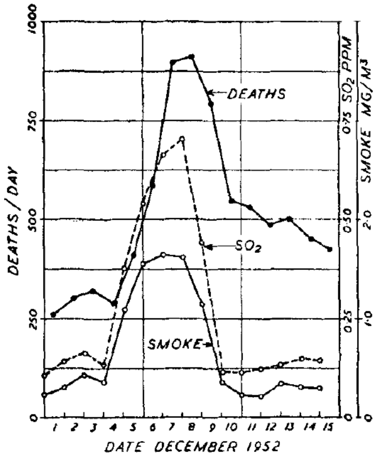


Figure 1. Daily air pollution and deaths.

Air pollution aspects of the London fog of December 1952

By E. T. WILKINS

D.S.I.R., Fuel Research Station, Greenwich

What's harmful part of the PM mix?

- The common approaches (Dominici et al 2003) :
    - Look at one pollutant at a time reflecting regulations and methodological issues (or in my view determining regulation!)
    - Have difficultly in separating effects from pollutants that occur at the same time (high correlation) or have effects that increase together.
    - Pairs of pollutants are assessed together to test if the result for one pollutant is confounded by another.
    - Effect estimates can depend on how well exposure of a city population is captured by a single monitoring site (locally varying vs regional pollutants)

(There's a very nice review by Oakes et al 2014, Env International , 69, 90-99)

What's harmful part of the PM mix?

- One valiant (and much cited)effort :
  - Particle number
  - Black smoke
  - Sulphate
  - Nitrate
  - PM10 by TEOM and gravimetric
  - PM2.5 by TEOM and gravimetric
  - Primary PM10
  - Non-primary PM10, PM2.5
  - Non-primary coarse PM

Urban Ambient Particle Metrics and Health

A Time-series Analysis

Richard W. Atkinson,[a] Gary W. Fuller,[b] H. Ross Anderson,[a] Roy M. Harrison,[c] and Ben Armstrong[d]

Background: Epidemiologic evidence suggests that exposure to ambient particulate matter is associated with adverse health effects. Little is known, however, about which components of the particulate mixture (size, number, source, toxicity) are most relevant to health. We investigated associations of a range of particle metrics with daily deaths and hospital admissions in London.

particular because exposures were based upon data from a single centrally located monitoring site. There is a need for replication with more comprehensive exposure data, both in London and elsewhere.

(*Epidemiology* 2010;21: 501–511)

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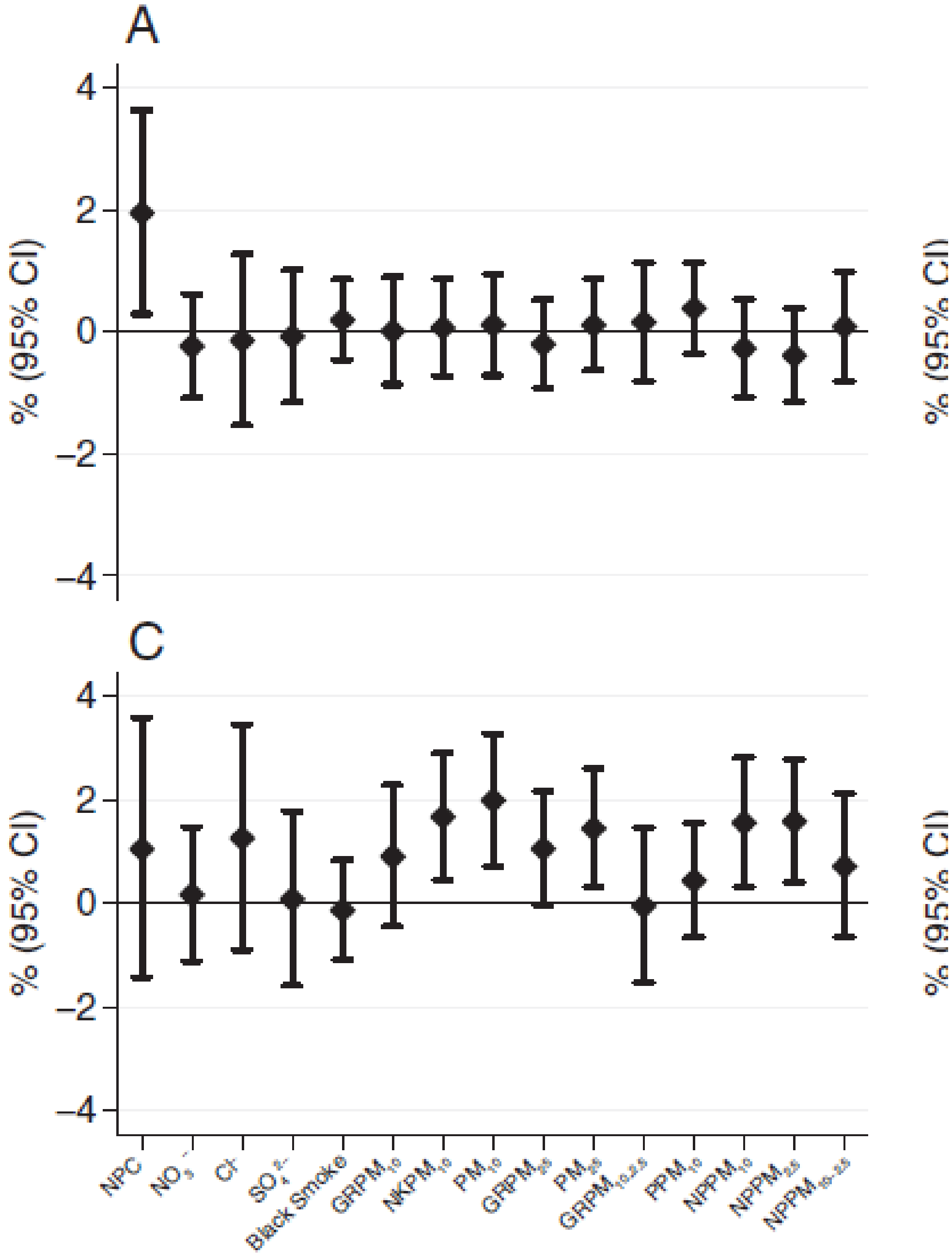

Cardiac mortality

Respiratory mortality

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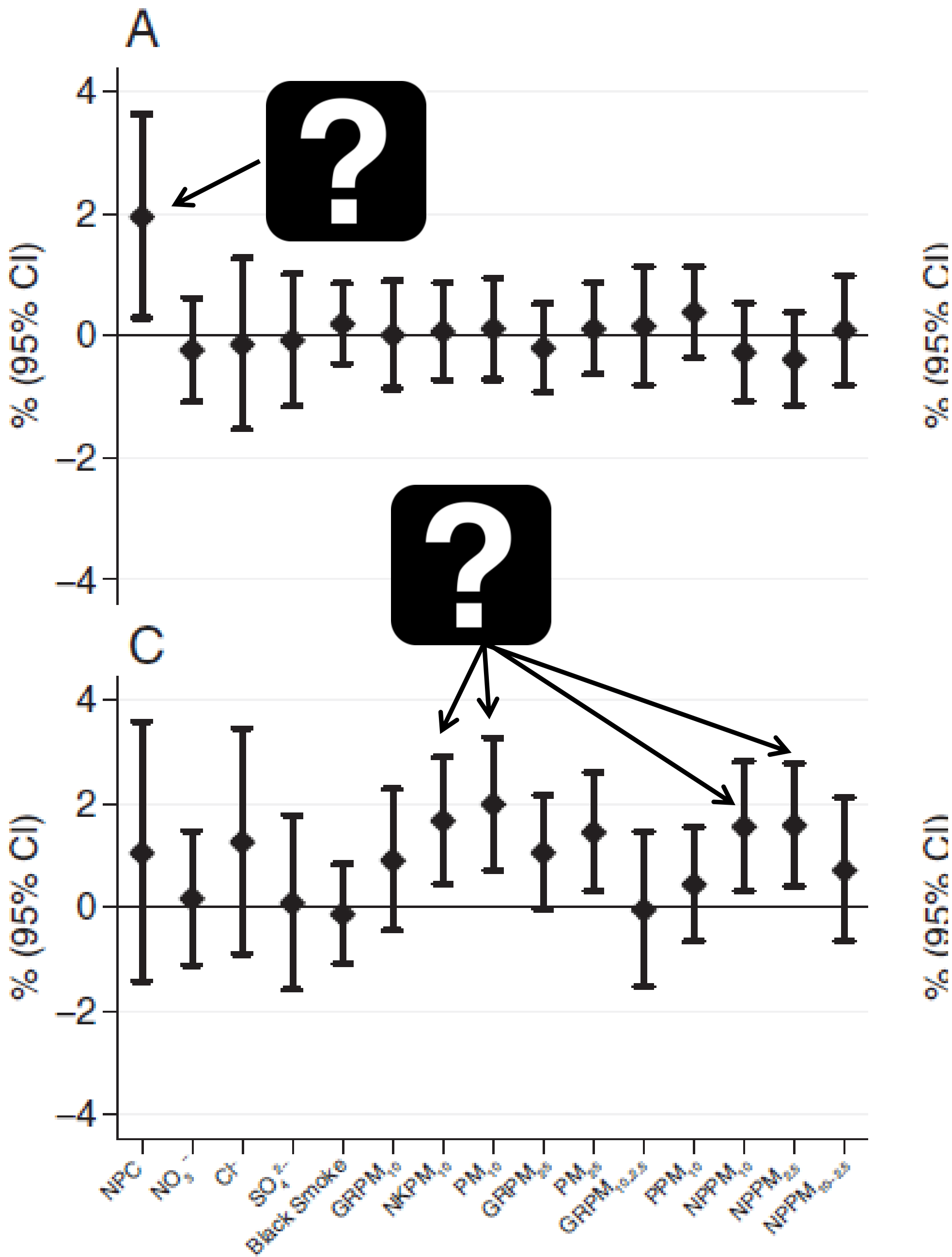

Cardiac mortality

Respiratory mortality

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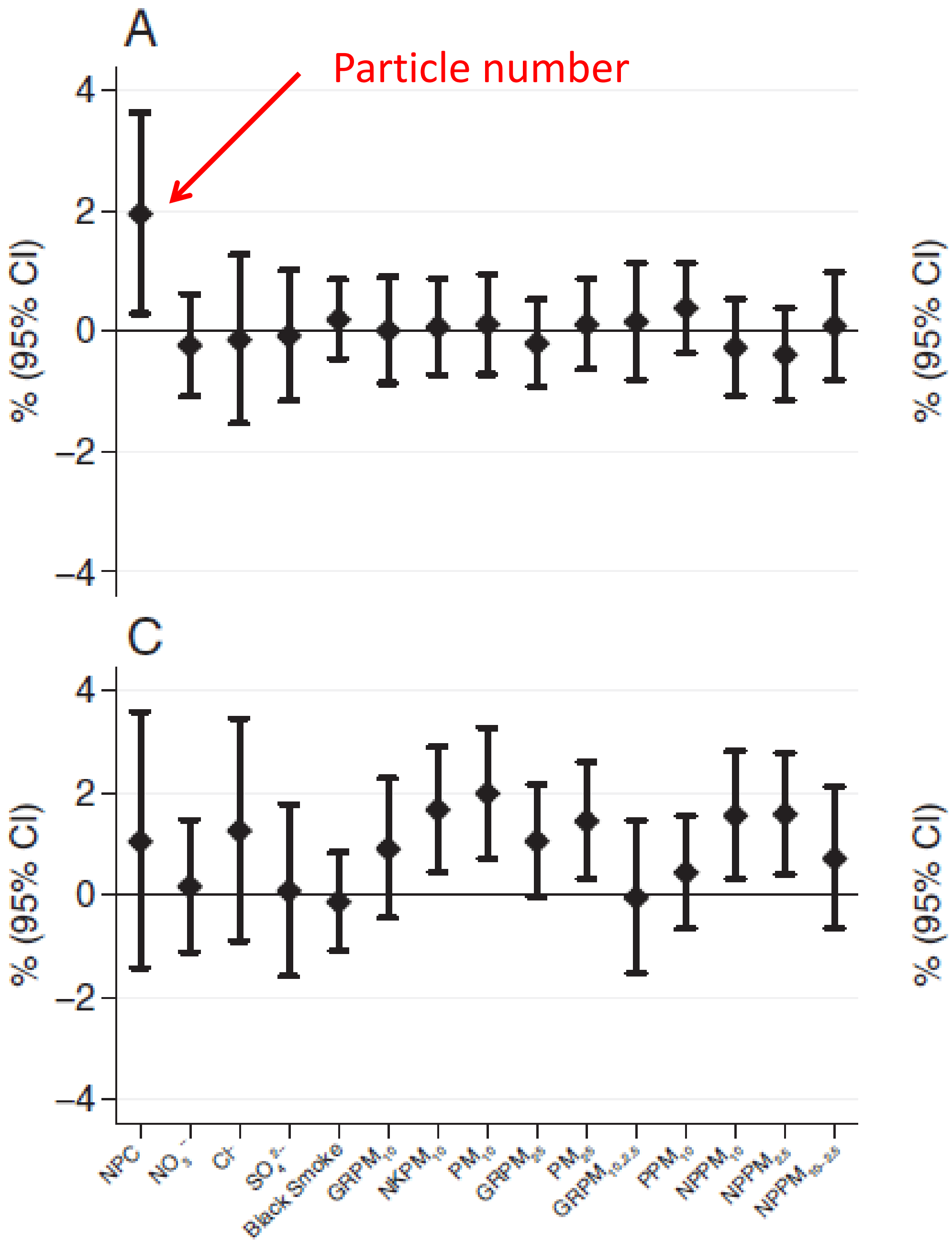

Cardiac mortality

Respiratory mortality

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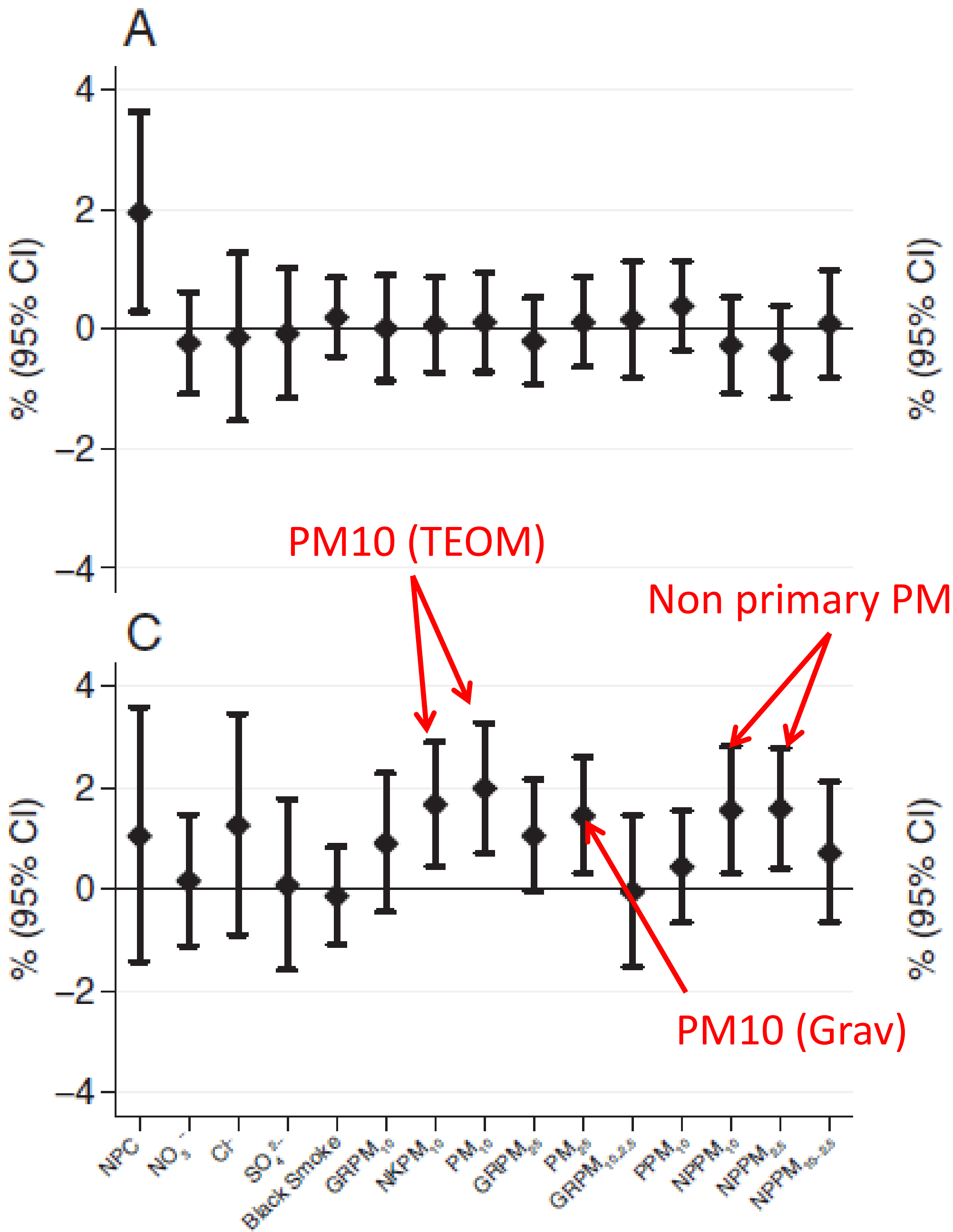

Cardiac mortality

Respiratory mortality

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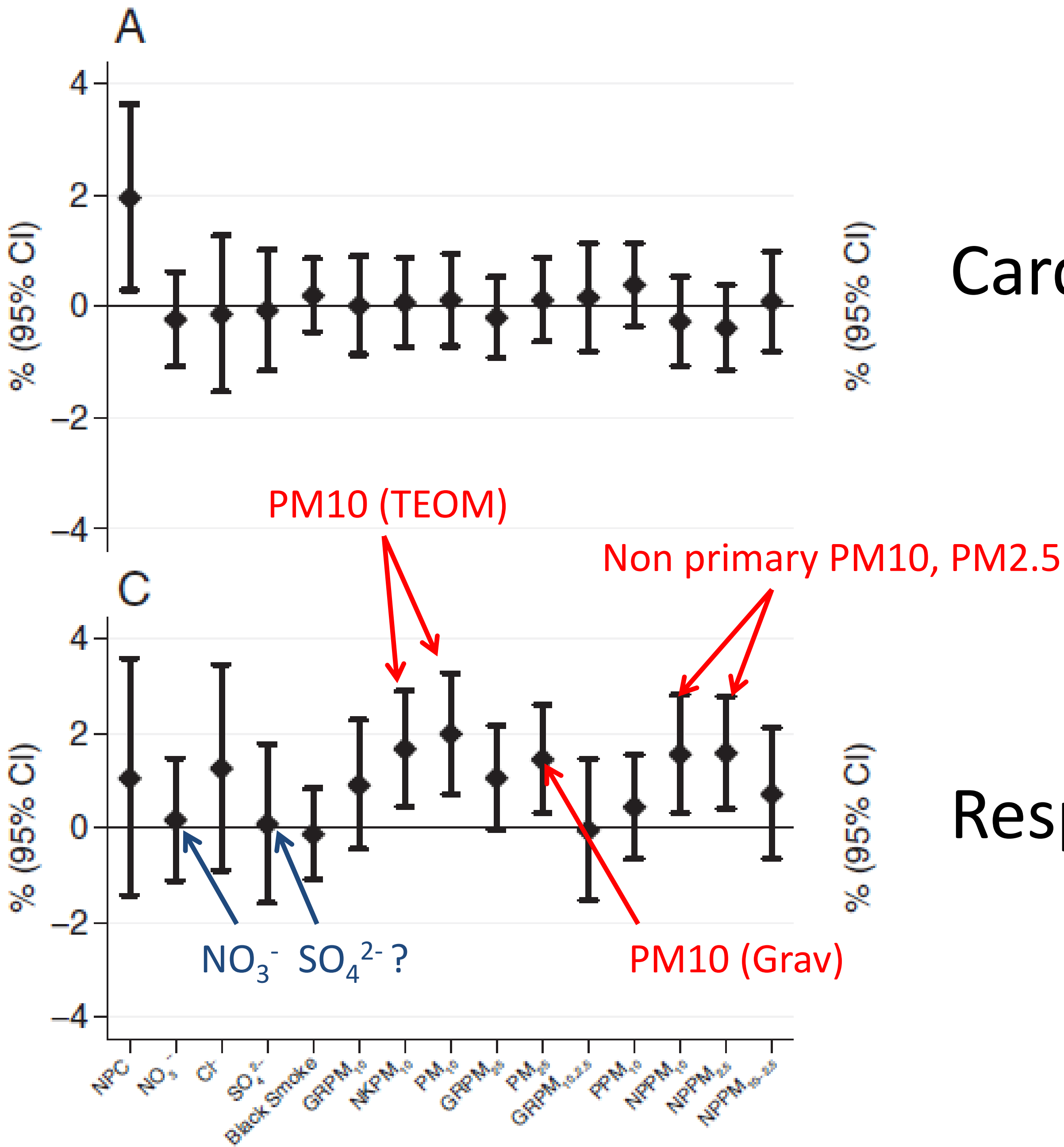

Cardiac mortality

Respiratory mortality

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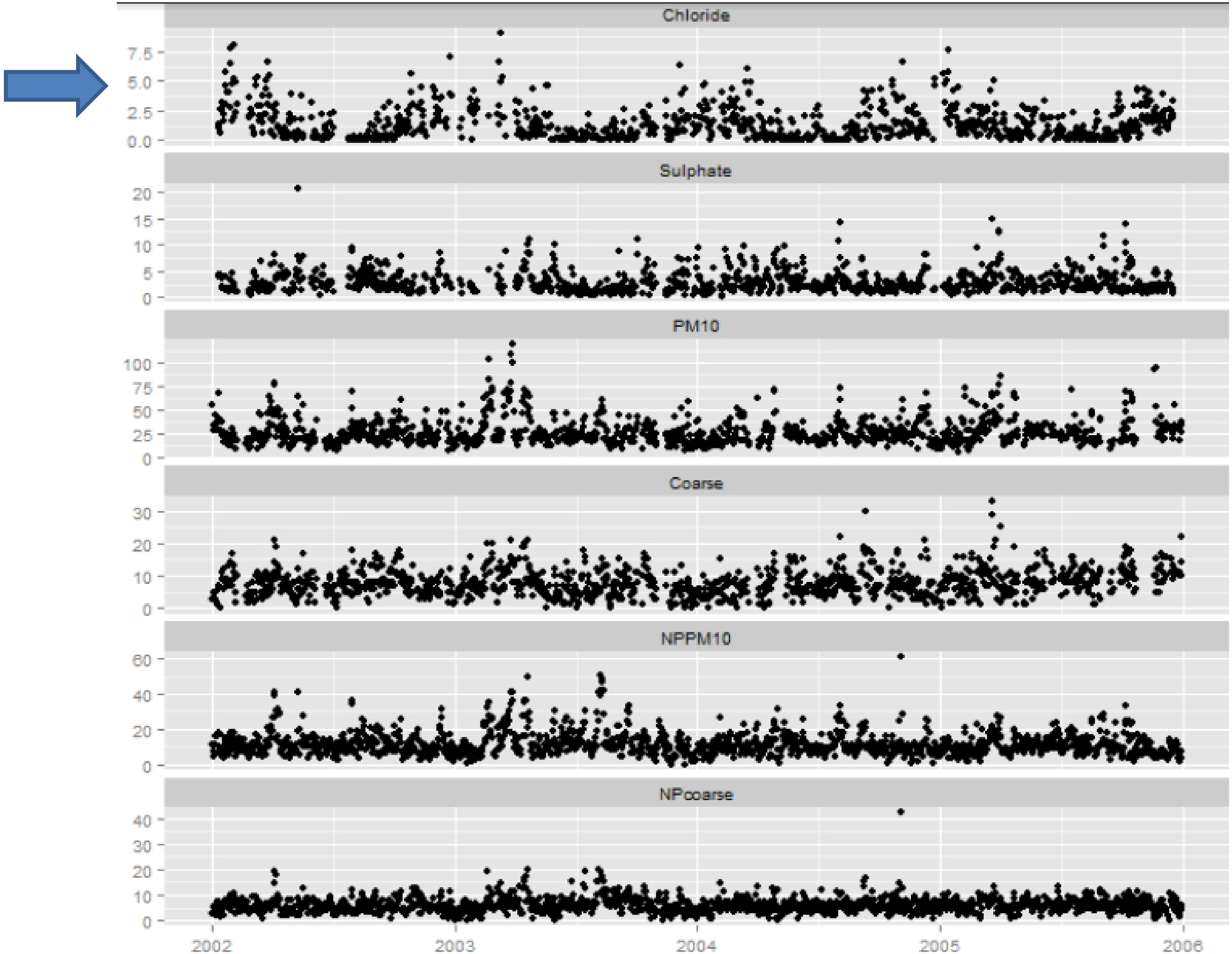
..do we need to think differently about this?

- The single pollutant approach assumes that we are exposed to one pollutant

- (albeit with tests for confounding by another pollutant).



Chloride
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2.5
0.0
Sulphate
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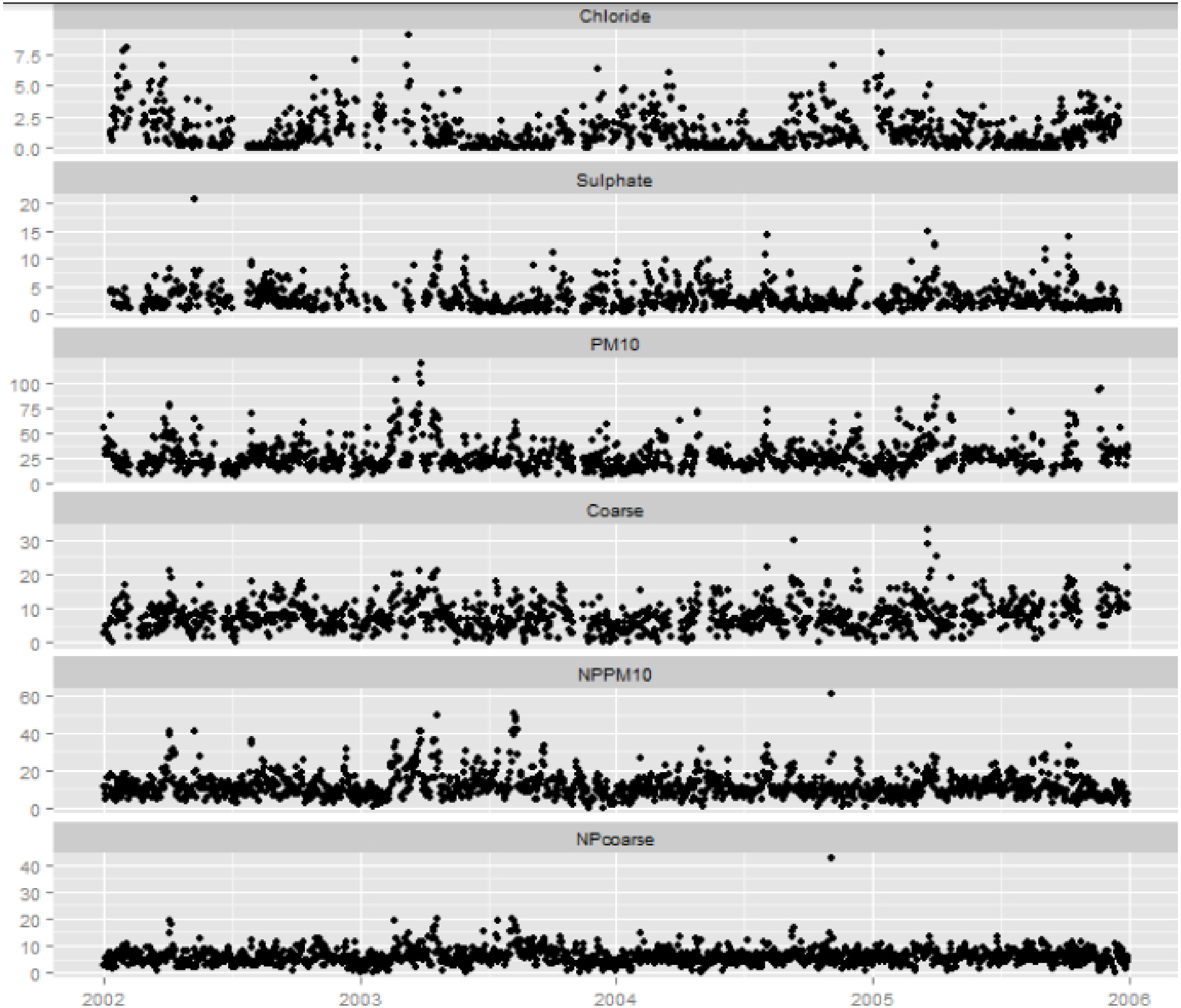
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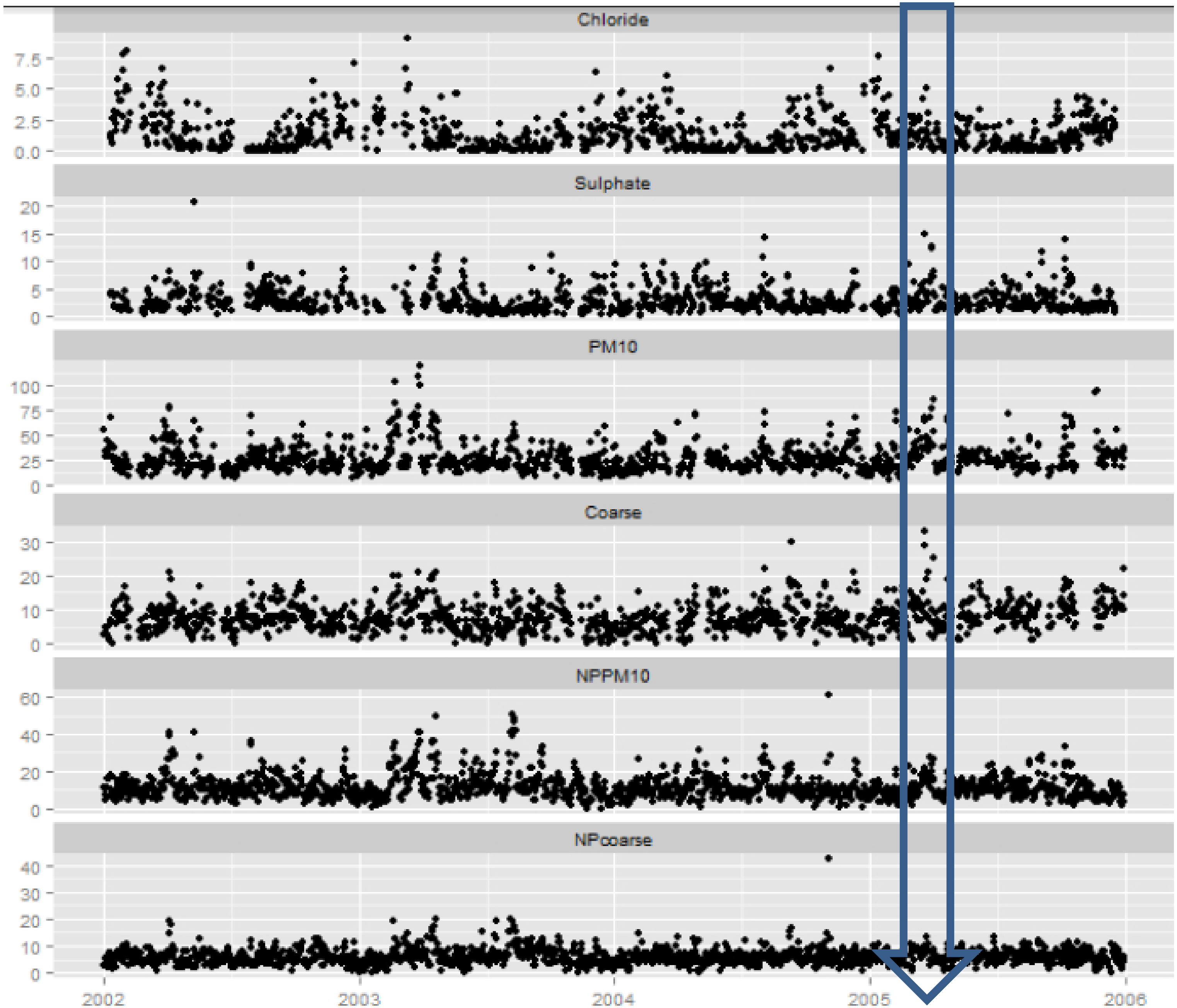

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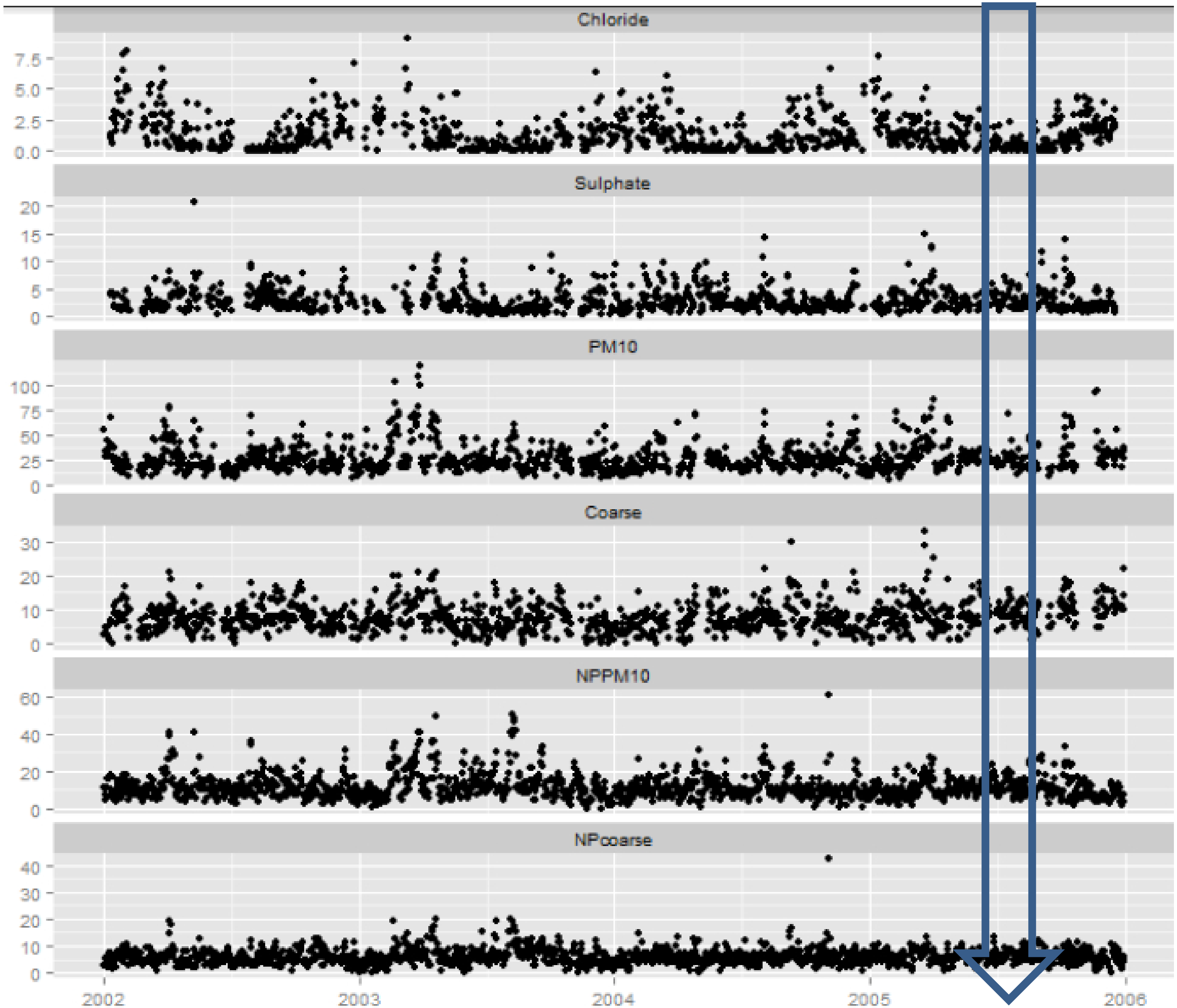
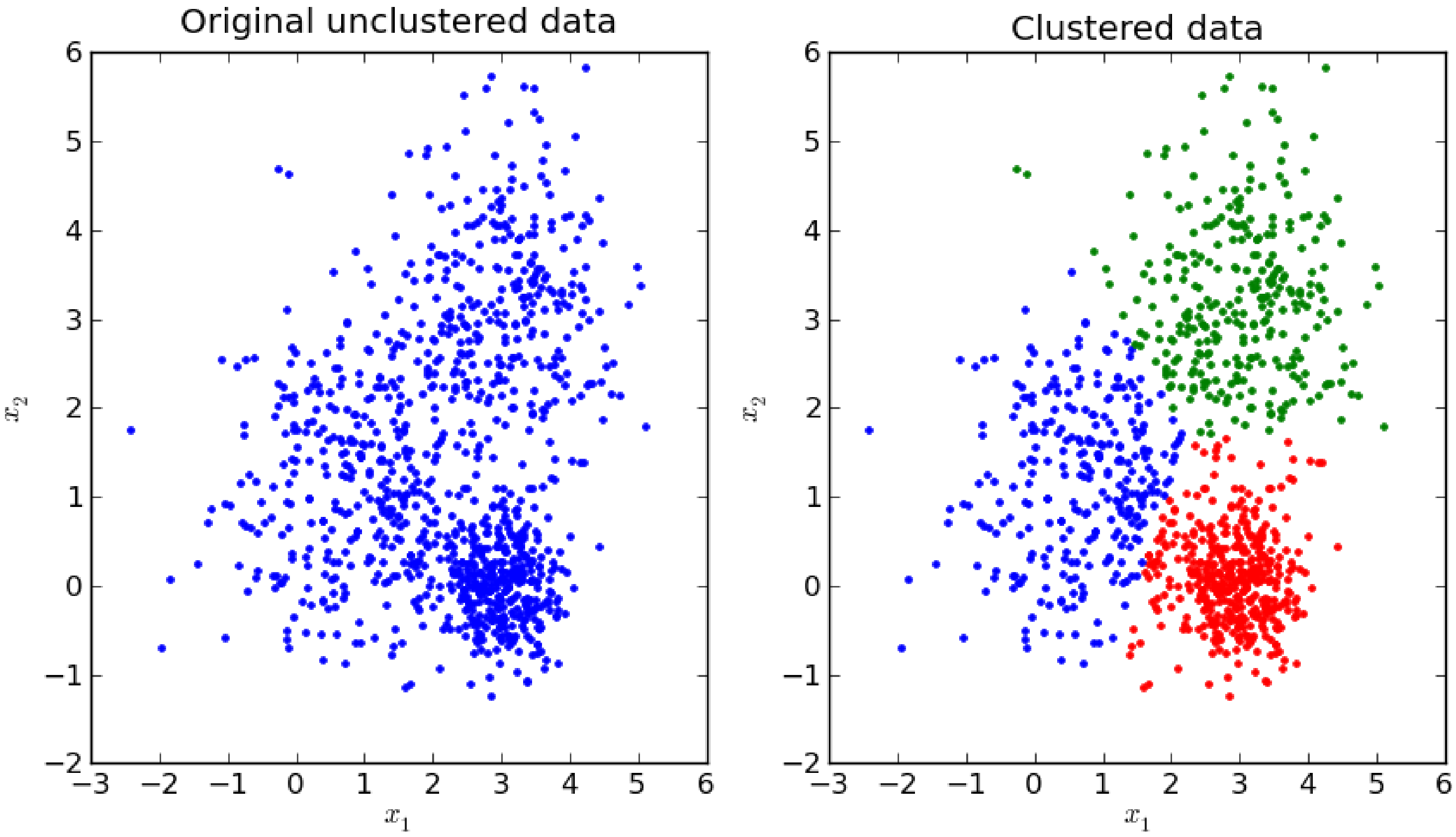


Chloride
Sulphate
PM10
Coarse
NPPM10
NPcoarse
2002
2003
2004
2005
2006

Group (or cluster) similar days



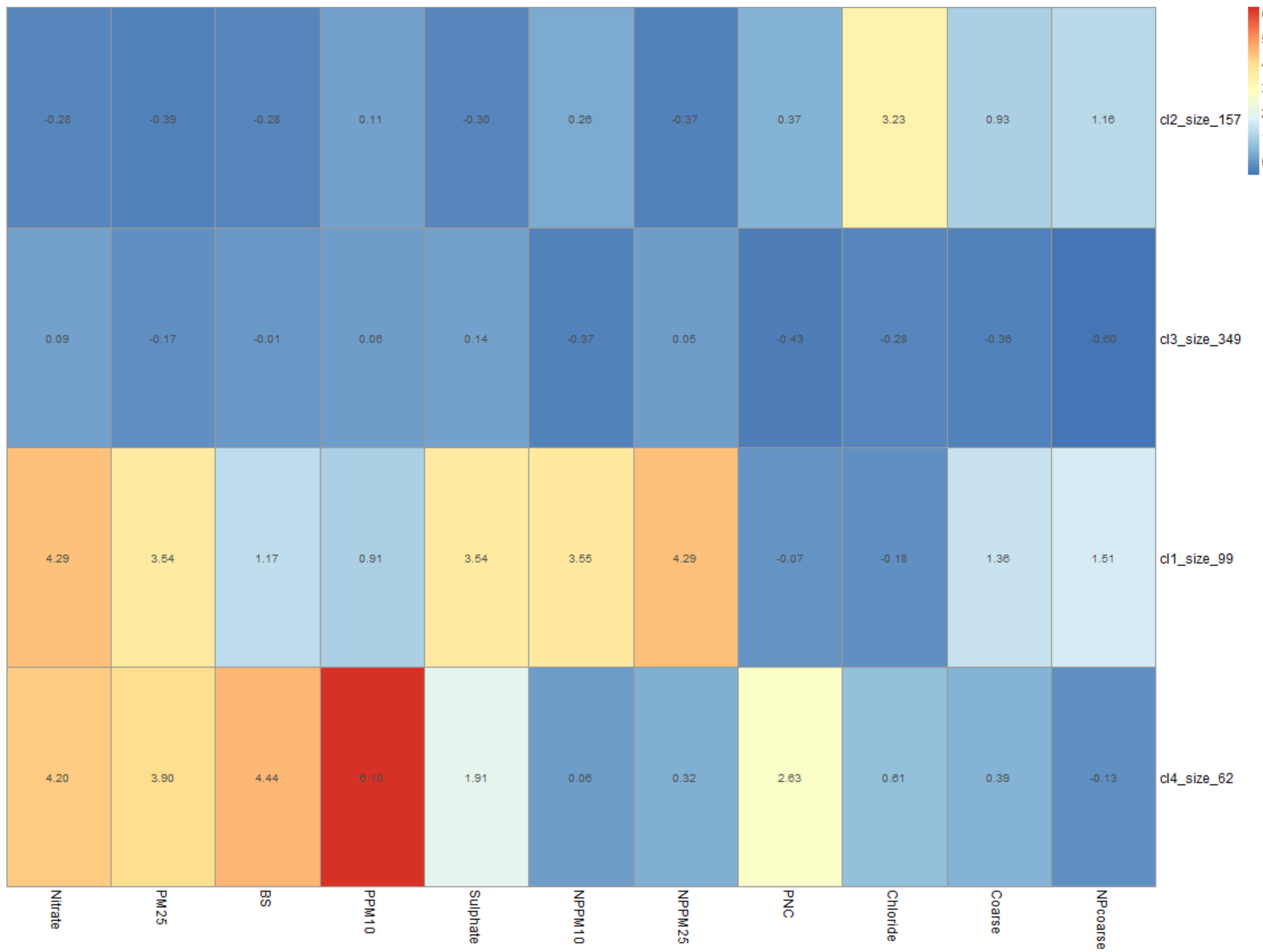
K- means to cluster similar days according to their pollution (only days with all metrics)

2) Chloride 157 days

3) Nothing distinct 349 days

1) Secondary 99 days

4) Primary & NO3 82 days



Why not use the health data to help clustering ?

- Cluster days with similar air pollution mixture and similar health effects
- Profile regression (Molitor et al. 2010) - a Bayasian non-parametric mixture model and Dirichlet process.
- Spline functions on time and temperature as before

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Analysing the health effects of simultaneous exposure to physical and chemical properties of airborne particles

Monica Pirani [a,*], Nicky Best [b], Marta Blangiardo [b], Silvia Liverani [c,d,e], Richard W. Atkinson [f], Gary W. Fuller [a]

Respiratory mortality

- Risks relative to mean:
- Cluster 1: 0.98 (95% PI: 0:96; 1:00)
- Cluster 2: 1:00 (95% PI: 0.97, 1.03) (Mainly primary)
- Cluster 3: 1:02 (95% PI: 1:00; 1:04) (SO4, NO3, NPM10...)

Table 3: Summary of cluster profiles (on original scale): distribution means (95% PI) for characteristics of clusters from the representative clustering.

Particle compounds	cluster 1 (1156 days)	cluster 2 (63 days)	cluster 3 (242 days)
PNC ($n/cm^3/1000$)	20.08 (19.54, 20.67)	27.01 (23.63, 30.42)	24.56 (22.58, 26.51)
Chloride ($\mu g/m^3$)	1.38 (1.28, 1.47)	1.43 (0.95, 1.90)	0.90 (0.62, 1.21)
Nitrate ($\mu g/m^3$)	2.90 (2.73, 3.41)	3.76 (2.19, 7.74)	8.58 (6.49, 9.90)
Sulphate ($\mu g/m^3$)	2.61 (2.49, 2.79)	2.65 (1.73, 4.54)	4.76 (3.94, 5.50)
BS ($\mu g/m^3$)	5.48 (5.33, 5.76)	9.80 (7.59, 11.57)	8.83 (7.65, 9.82)
PM_{10} ($\mu g/m^3$)	23.16 (22.51, 25.48)	37.24 (26.94, 45.09)	42.52 (37.61, 47.25)
$PM_{2.5}$ ($\mu g/m^3$)	15.65 (15.12, 17.40)	28.45 (19.10, 35.12)	32.09 (26.84, 35.82)
Coarse ($\mu g/m^3$)	7.57 (7.32, 7.88)	8.87 (7.23, 10.57)	10.36 (8.82, 12.00)
PPM_{10} ($\mu g/m^3$)	3.95 (3.82, 4.22)	7.61 (5.95, 9.70)	7.10 (5.79, 8.06)
$NPPM_{10}$ ($\mu g/m^3$)	10.27 (9.97, 10.73)	11.93 (7.68, 15.86)	17.32 (15.21, 19.46)
$NPPM_{2.5}$ ($\mu g/m^3$)	4.56 (4.34, 5.01)	12.04 (5.41, 18.76)	10.90 (8.74, 12.27)
NPcoarse ($\mu g/m^3$)	5.76 (5.61, 5.91)	5.70 (4.87, 6.63)	6.96 (6.12, 7.86)

Respiratory mortality

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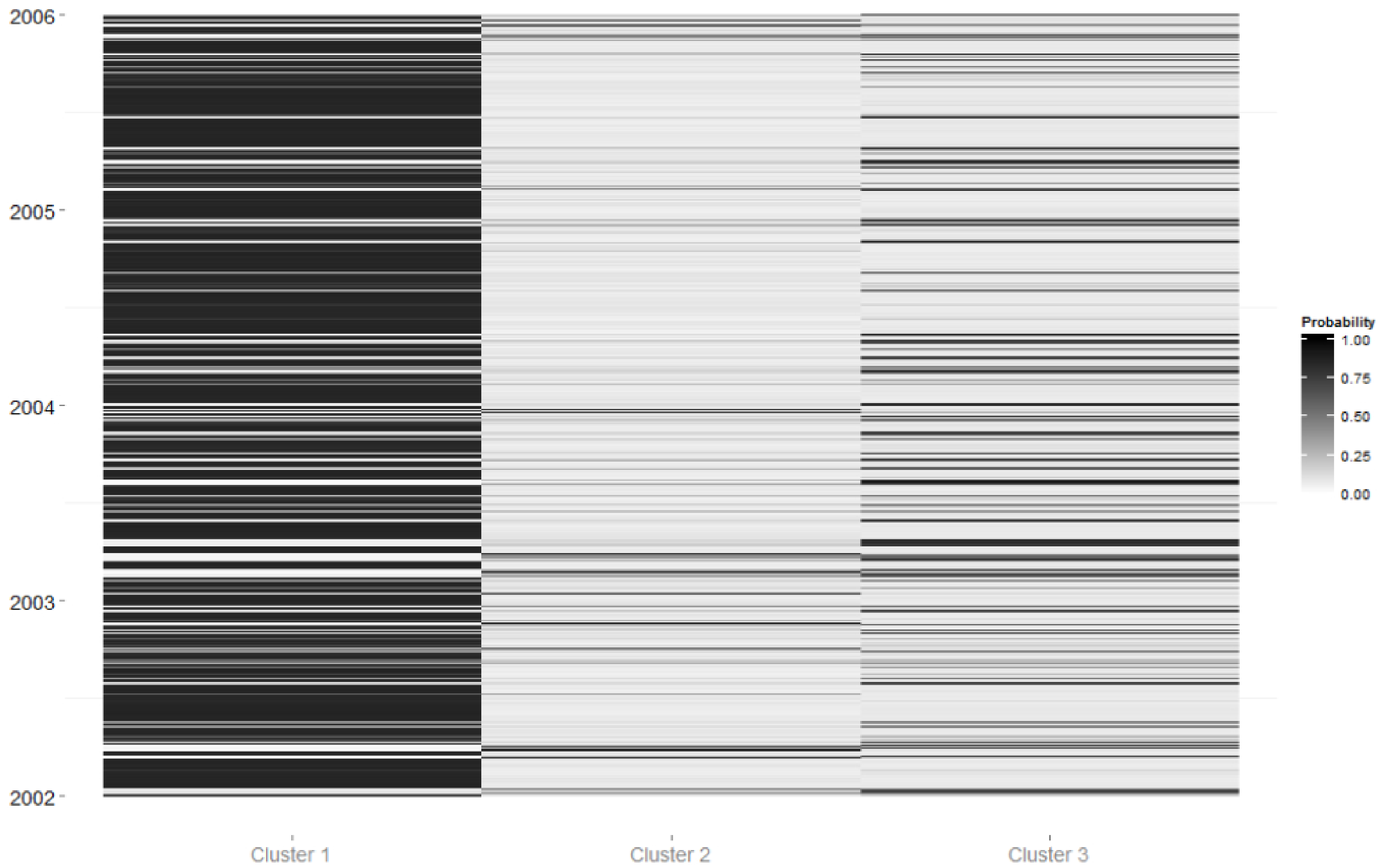
Respiratory mortality



Health impact of changing PM concentrations

- Many policy levers have been applied to decrease PM concentrations.

  - Decreases in secondary pre-cursers (eg large combustion)
  - Particle number concentrations (decreased by ~40% at London background with ultra low S diesel - Jones et al 2012).
  - Euro classes exhaust programme
  - Urban primary emissions (vehicle exhausts standards, LEZ, London Mayor’s policies etc)

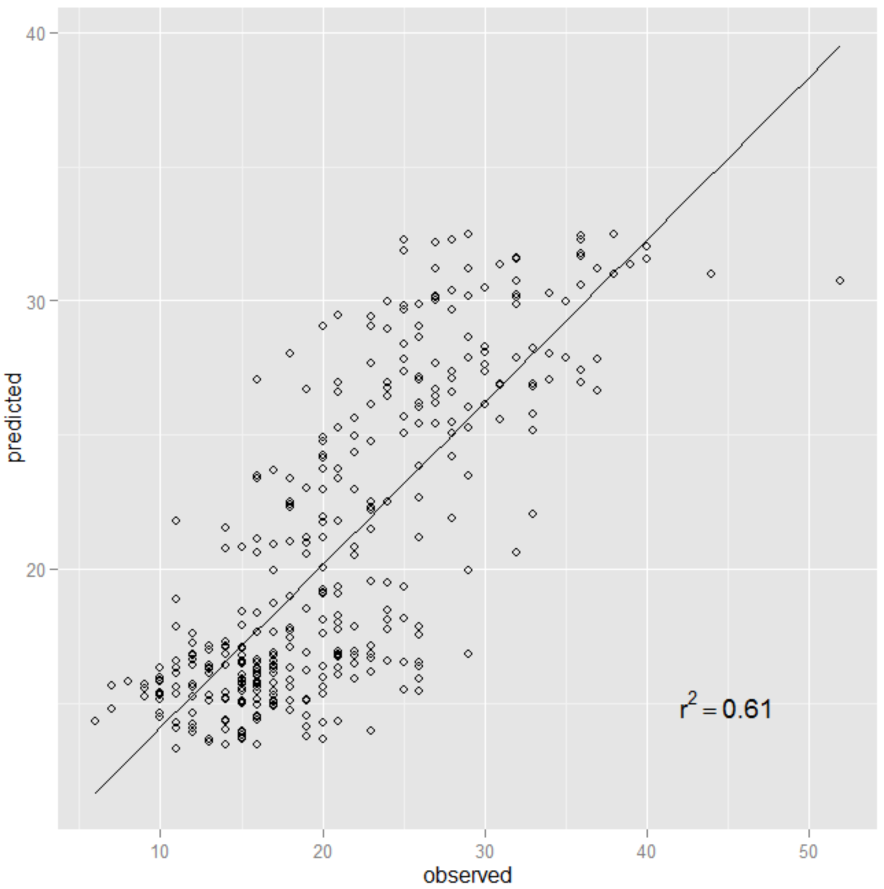
These don’t affect one pollutant at a time but change the measured PM mixture.

Health impact of changing PM concentrations

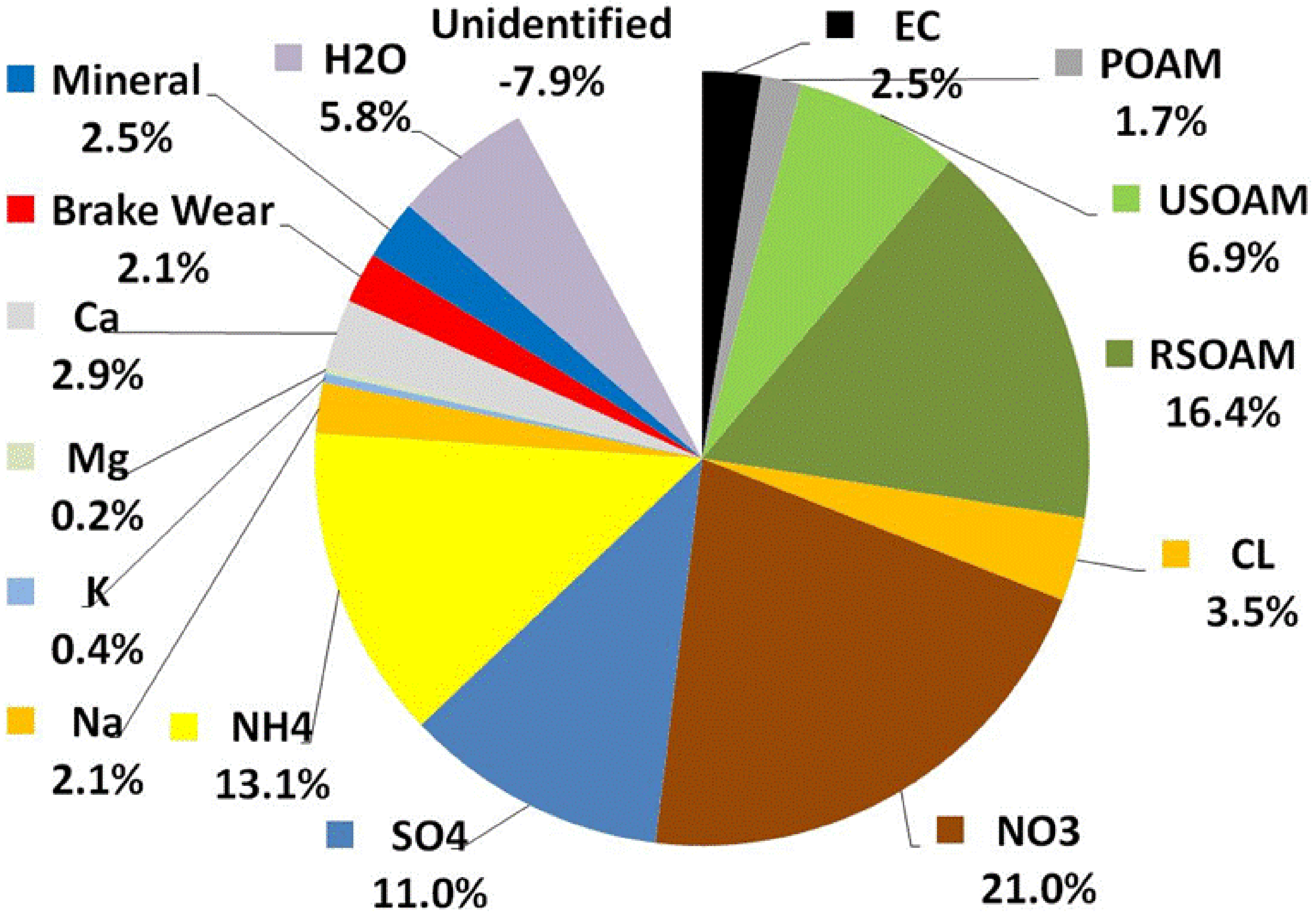
Air particles	2002-2005					2012				
			Percentiles					Percentiles		
	Mean	Range	25th	50th	75th	Mean	Range	25th	50th	75th
PNC $(n/cm^3/1000)$	21.19	5.39-52.44	14.63	19.97	25.91	12.12	5.34-25.02	9.16	11.49	14.57
CI^- $(\mu g/m^3)$	1.31	0.01-9.06	0.25	0.88	1.98	1.37	0.20-6.40	0.50	1.10	1.80
NO_3^- $(\mu g/m^3)$	3.77	0.03-30.89	1.35	2.44	4.47	3.33	0.10-34.40	0.70	1.60	4.00
SO_4^{2-} $(\mu g/m^3)$	2.93	0.23-20.63	1.51	2.25	3.89	1.67	0.20-13.50	0.80	1.30	2.10
BS $(\mu g/m^3)$	6.23	1.40-31.33	4.00	5.40	7.60	5.88	1.11-27.78	3.33	4.44	7.41
PM_{10} $(\mu g/m^3)$	26.63	5.00-119.00	17.00	23.00	32.00	17.70	4.00-76.00	11.00	14.00	20.75
$PM_{2.5}$ $(\mu g/m^3)$	18.85	1.00-104.00	11.00	15.00	22.00	11.31	2.00-61.00	6.00	8.00	13.00
Coarse $(\mu g/m^3)$	7.89	0-33.00	5.00	7.00	10.00	6.60	0-31.00	4.00	6.00	8.00
PPM_{10} $(\mu g/m^3)$	4.63	0.80-39.10	2.50	3.70	5.60	4.11	1.00-14.40	2.30	3.20	5.30
$NPPM_{10}$ $(\mu g/m^3)$	11.50	0-61.00	7.00	9.90	14.20	9.49	1.17-29.61	6.12	8.46	11.88
$NPPM_{2.5}$ $(\mu g/m^3)$	5.75	0-32.60	2.40	4.20	7.40	3.42	0-17.54	1.35	2.63	4.33
NP coarse $(\mu g/m^3)$	5.99	0-42.20	4.00	5.60	7.40	6.40	0.24-13.47	4.69	6.21	8.00

Health impact of changing PM concentrations

- Can be used predicatively:
  - Used 2002-2004 as a training set to predict 2005 respiratory mortality
  - Predicted 2005 according to the PM that prevailed in 2012.
  - Decrease of 3.5% (95% PI: -0.12%, -5.74%) in resp. mortality; around 270 people as an annual total.

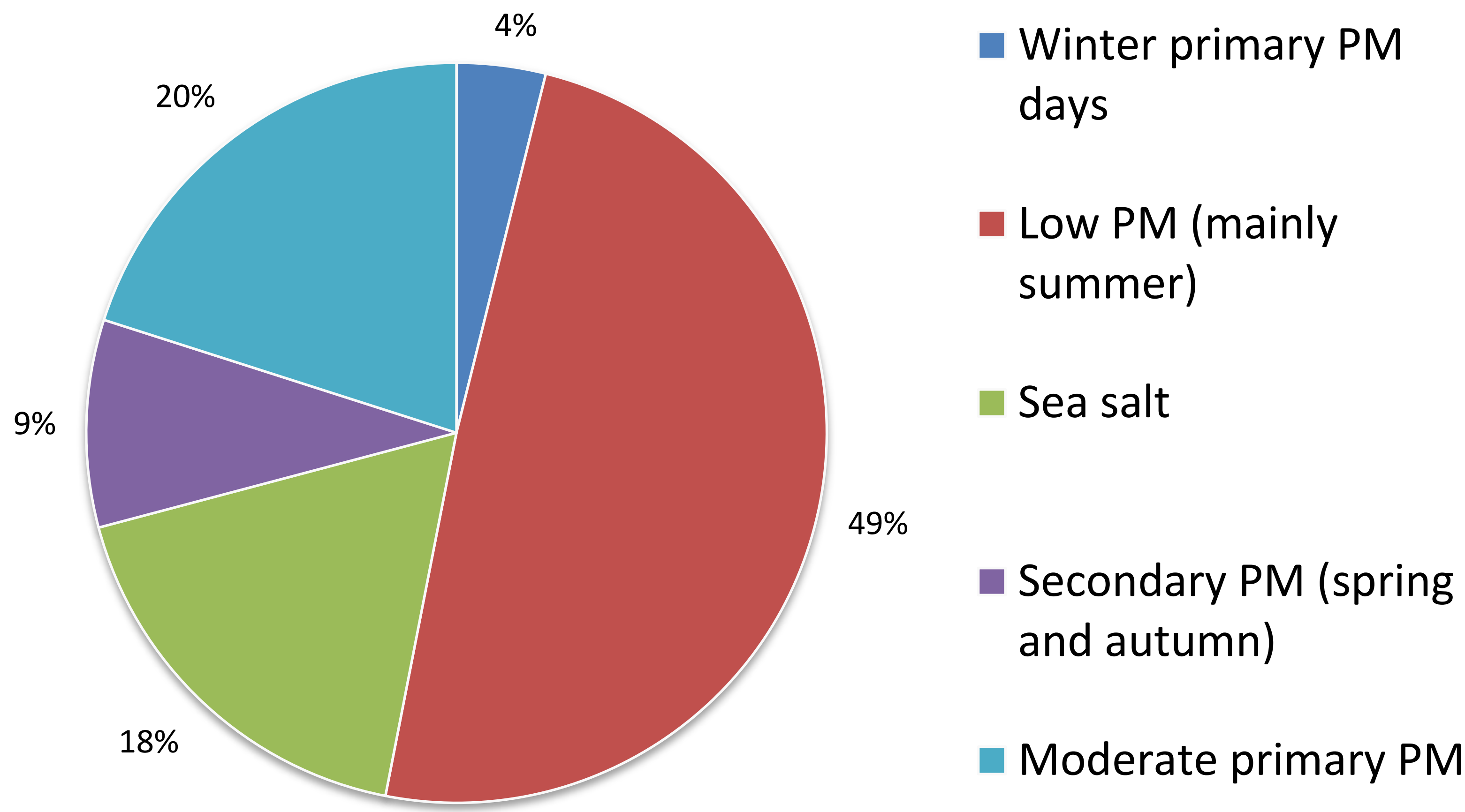


North Kensington – time to change our view?



North Kensington – time to change our view?

- using measurements from NERC ClearfLo and Traffic



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Conclusion - new opportunities

- We need new health studies to find the smoking gun in the PM mix but this requires new statistical approaches.

- A mixture approach is a paradigm shift better reflecting the realities of pollution exposure.

  - So far looking at mixtures of PM and health effects suggests that spring secondary episodes (based on 2000 to 2005) present greatest risk for respiratory deaths - 2%. See also Smith et al (2015).

  - Changes in a multitude of PM sources 2005 – 2012 is estimated to have decreased London's reparatory deaths by 3.5% (~270 people per year).

  - Note: this result was peer reviewed but is 1st time this approach has been used and we need consensus before that figure can be confirmed.

- Controlling secondary PM → decrease in NOX (traffic, industry), SO2 (industry) and OC (traffic and industry again) with cities acting together across a region and NH4 (farming!).

- New detailed composition measurements in London will allow new opportunities so we can better answer questions like how will combating NO2 help PM2.5 health effects?

Thanks to…

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Monica Pirani

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Anna Font

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