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Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality

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OBJECTIVES

(i) An update of the national analysis

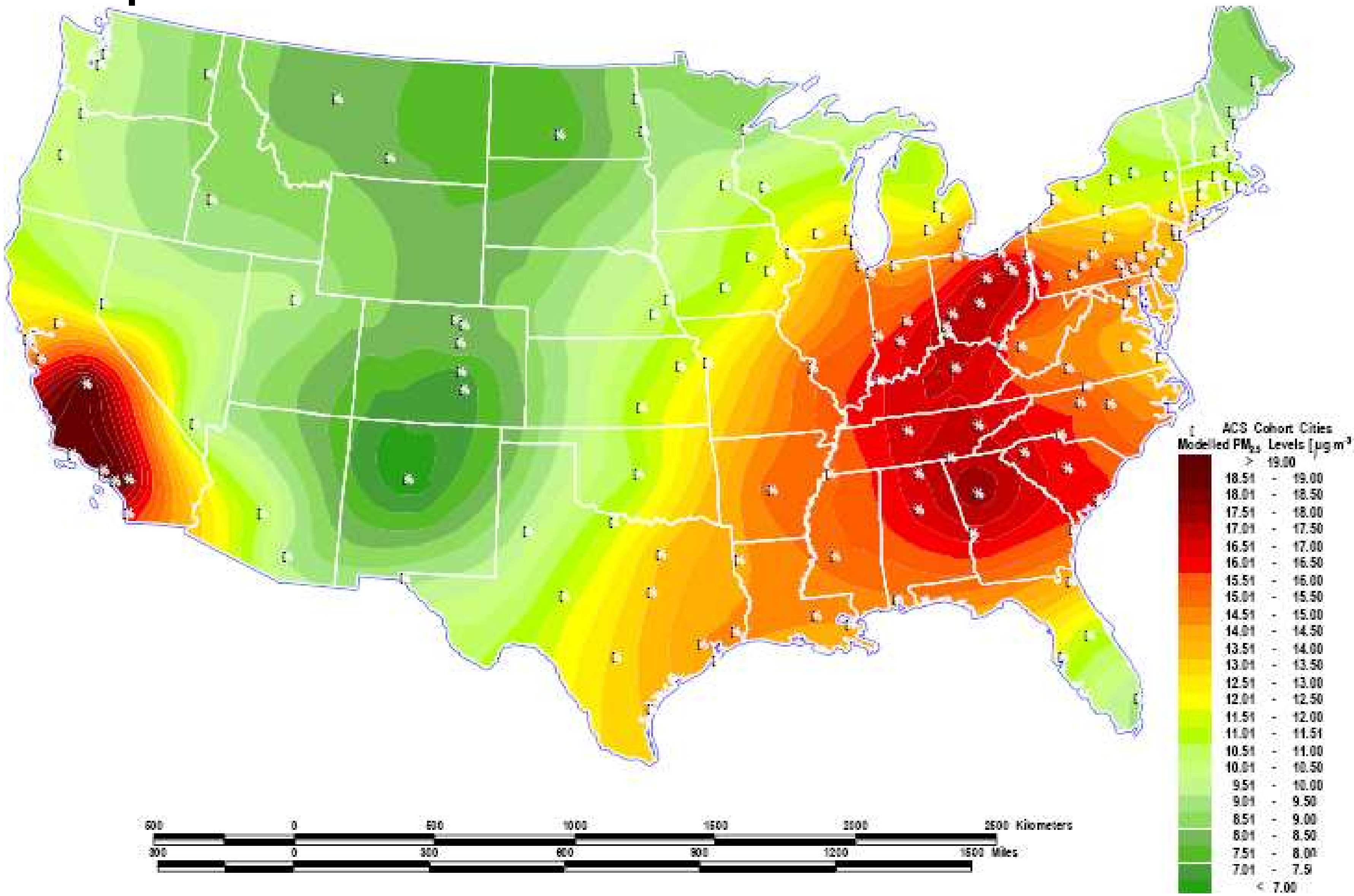
a) to assess the confounding and modifying effect of community and neighbourhood level ecological covariates on the air pollution–mortality association at various scales;

b) to assess how spatial autocorrelation and multiple levels can be taken into account within the random effects Cox Model;

(iii) to assess the impact of refinement of air pollution exposure to the within-city or intraurban scale using land-use regression on the size and significance of health effects in Los Angeles and New York; and

(iv) to evaluate critical exposure time windows most relevant for the air pollution-mortality association.

Spatial distribution (kriged) of fine particles in the year 1999-2000 (mean)



HRs of pollution risk factors for selected causes of death with follow-up from 1982 to 2000, adjusting for 44 individual level covariates and stratifying the baseline hazard function by age, gender, and race using the standard Cox survival model (95% CIs).

Covariate	Number of MSA & Subjects	Level of Relative Risk	All Causes	Cardiopulmonary	Cause of Death Ischemic Heart Disease	Lung Cancer	All Other Causes
$PM_{2.5}$ (1979-1983)	58 351338	10 $\mu g/m^3$	1.03 (1.01, 1.04)	1.06 (1.04, 1.08)	1.12 (1.09, 1.16)	1.08 (1.03, 1.14)	0.98 (0.96, 1.00)
$PM_{2.5}$ (1999-2000)	116 499968	10 $\mu g/m^3$	1.03 (1.01, 1.05)	1.09 (1.06, 1.12)	1.15 (1.11, 1. 20)	1.11 (1.04, 1.18)	0.97 (0.94, 1.00)
SO_4 (1980)	147 572312	5 $\mu g/m^3$	1.04 (1.03, 1.05)	1.04 (1.02, 1.05)	1.06 (1.04, 1.08)	1.05 (1.02, 1.09)	1.03 (1.02, 1.05)
SO_4 (1990)	52 268336	5 $\mu g/m^3$	1.07 (1.05, 1.09)	1.06 (1.03, 1.09)	1.14 (1.10, 1.19)	1.04 (0.97, 1.11)	1.08 (1.05, 1.11)
SO_2 (1980)	115 513450	5 ppb	1.02 (1.02, 1.03)	1.02 (1.01, 1.03)	1.04 (1.02, 1.05)	1.00 (0.98, 1.02)	1.02 (1.02, 1.03)
PM_{15} (1979-1983)	57 345824	15 $\mu g/m^3$	1.01 (1.00, 1.02)	1.03 (1.02, 1.05)	1.06 (1.04, 1.08)	1.00 (0.97, 1.04)	0.99 (0.97, 1.00)

HRs of pollution risk factors for selected causes of death with follow-up from 1982 to 2000, adjusting for 44 individual level covariates and stratifying the baseline hazard function by age, gender, and race using the standard Cox survival model (95% CIs).

Covariate	Number of MSA & Subjects	Level of Relative Risk	All Causes	Cardiopulmonary	Cause of Death Ischemic Heart Disease	Lung Cancer	All Other Causes
O_3 (1980)	118 531826	10 ppb	1.00 (0.99, 1.01)	1.01 (1.00, 1.03)	1.01 (0.98, 1.03)	1.00 (0.96, 1.04)	0.99 (0.97, 1.00)
O_3 (1980–April-Sept)	118 531185	10 ppb	1.02 (1.01, 1.02)	1.03 (1.02, 1.04)	1.01 (0.99, 1.02)	0.99 (0.96, 1.02)	1.01 (1.00, 1.02)
NO_2 (1980)	76 406917	10 ppb	0.99 (0.99, 1.00)	1.01 (1.00, 1.02)	1.02 (1.00, 1.03)	0.99 (0.97, 1.01)	0.98 (0.97, 0.99)
CO (1980)	108 508538	1 ppm	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.01 (0.99, 1.03)	0.99 (0.97, 1.03)	0.99 (0.98, 1.01)

ECOLOGICAL COVARIATES

- **Air Conditioning (%)**
- **Grade 12 (%)**
- **Non White (%)**
- **Unemployment (%)**
- **Household Income ($000s)**
- **Income Disparity (GINI)**
- **Poverty (%)**

- Covariates were examined at the zip code level (ZCA), the metropolitan statistical area level (MSA
- Hazard ratios tended to increase with adjustment for ecologic covariates, although many of the differences were small.

SPATIAL AUTOCORRELATION

- The inclusion of spatial autocorrelation at both the MSA and ZCA levels increased the variance of the random effects, and widened the CIs for the $PM_{2.5}$ HR, providing some evidence of spatial clustering of residual mortality coinciding with the spatial pattern of $PM_{2.5}$

EXPOSURE-TIME WINDOWS

- Is there a critical exposure-time window that is primarily responsible for the increased mortality associated with ambient air pollution?
- Limited inter-individual temporal variation in exposures makes it difficult to identify the most critical period of exposure

INTRAURBAN ANALYSES

- **LOS ANGELES**
  - Results of the LA spatial analysis found health effects nearly three times greater than earlier analyses using between-community exposure contrasts.
- **NEW YORK**
  - Unlike the LA results, mortality for all-cause, cardiopulmonary, and lung cancer deaths was not elevated in the NYC spatial analysis; however, significant effects were seen for IHD.

INTRAURBAN ANALYSES

- Upon comparing subject characteristics in LA and NYC, it appeared unlikely that the differences observed among the national study and the two intraurban analyses were attributable differences in the underlying characteristics in each cohort group.

- The differences between NYC and LA may be attributable to fundamental differences in the topographical, geographical, and urban attributes of these two megalopolisis.

Evaluating the Effects of Ambient Air Pollution on Life Expectancy

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Table 1. Estimates of Increased Mortality Associated with an Increase in $PM_{2.5}$ Concentrations of 10 μg per Cubic Meter Based on Extended Follow-up of the American Cancer Society Cancer Prevention Study II.*

Cause of Death	Krewski et al., 2000†	Pope et al., 2002‡		Krewski et al., 2008§	
	$PM_{2.5}$ Monitoring 1979–1983, Follow-up 1989	$PM_{2.5}$ Monitoring 1979–1983, Follow-up 1998	$PM_{2.5}$ Monitoring 1999–2000, Follow-up 1998	$PM_{2.5}$ Monitoring 1979–1983, Follow-up 2000	$PM_{2.5}$ Monitoring, 1999–2000, Follow-up 2000
	percent increase in mortality (95% CI)				
All causes	4.8 (2.2 to 7.6)	3.1 (1.5 to 4.7)	3.2 (1.2 to 5.3)	2.8 (1.4 to 4.3)	3.6 (1.7 to 5.4)
Cardiopulmonary disease	10.1 (6.1 to 14.3)	7.1 (4.8 to 9.5)	9.2 (6.3 to 12.3)	7.0 (4.9 to 9.2)	10.0 (7.3 to 12.9)
Ischemic heart disease	12.2 (6.6 to 18.1)	13.0 (9.4 to 16.6)	14.3 (9.9 to 19.0)	13.3 (10.0 to 16.7)	15.5 (11.3 to 19.9)
Lung cancer	5.3 (−3.7 to 15.0)	8.9 (3.1 to 15.1)	11.6 (4.1 to 19.7)	7.5 (2.1 to 13.2)	10.9 (3.9 to 18.5)
All other causes	−0.2 (−4.2 to 4.0)	−1.9 (−4.3 to 0.5)	−4.7 (−7.6 to 1.8)	−2.1 (−4.3 to 0.0)	−4.7 (−7.3 to 2.0)

Health and Climate Change 5

Public health benefits of strategies to reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants

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ELEMENTAL CARBON

- Elemental carbon was associated with the greatest all-cause and cardiopulmonary mortality effect; however results were sensitive to the inclusion of the other air pollutants in the model.

- When using the actual distribution of air pollutant exposures in the U.S. as the risk scale in the survival models, sulphate was associated with the greatest mortality effect, with results robust to multi-pollutant adjustment.