Health Effects of Exposure to Air Pollution

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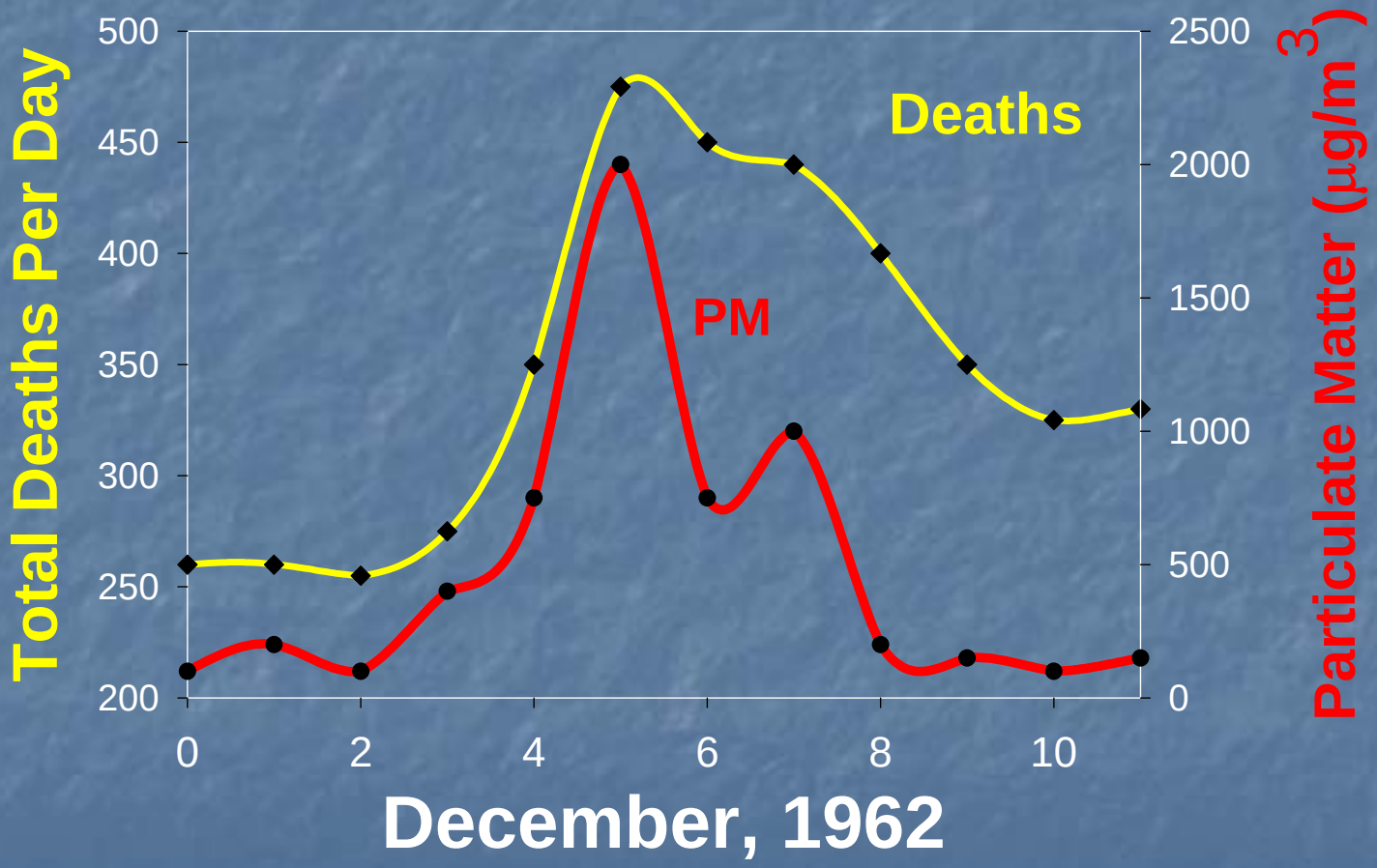
Short-Term Effects

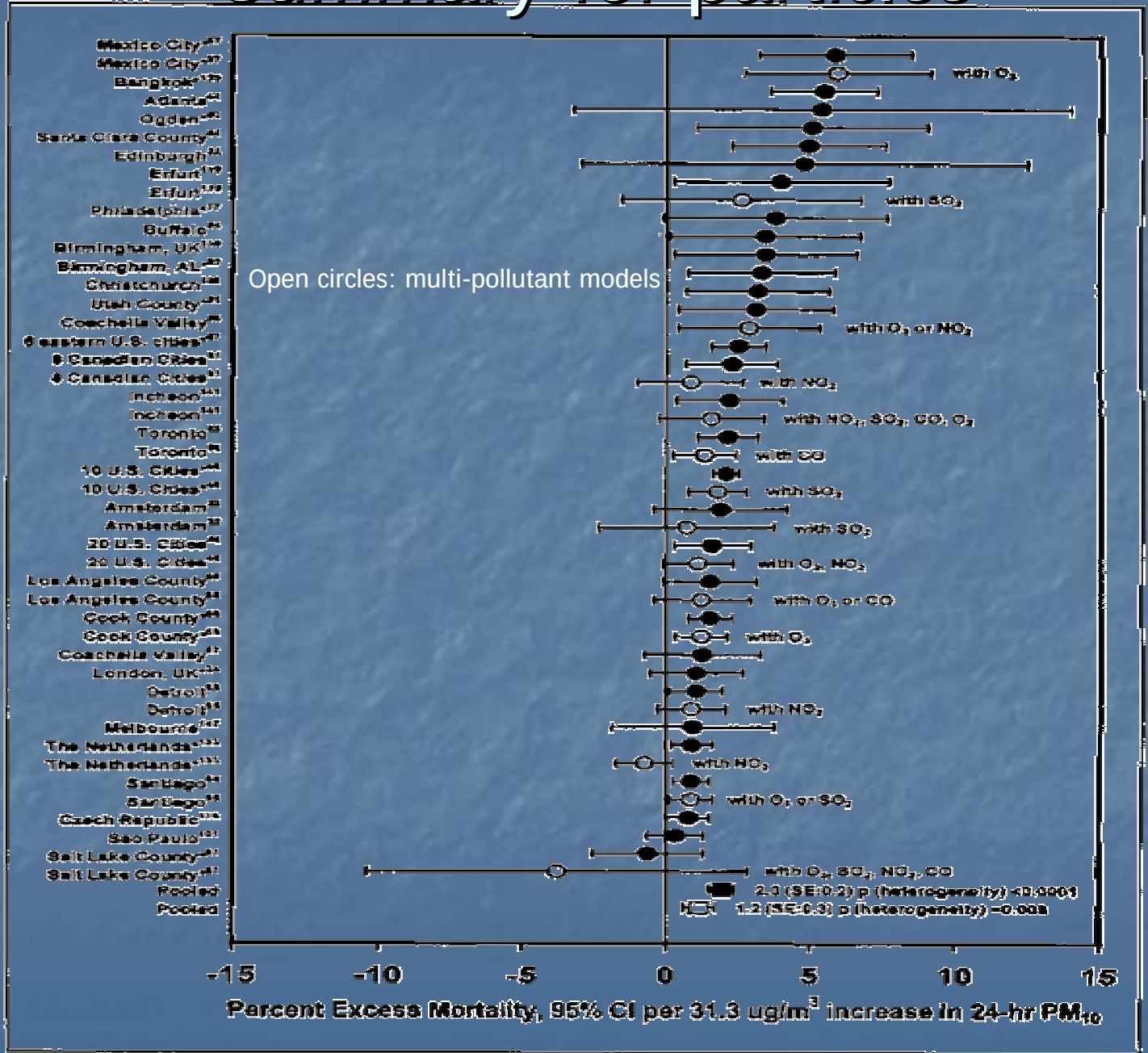
Question:

- Does the number of deaths on a particular day increase if air pollution increases on that day or on previous days?

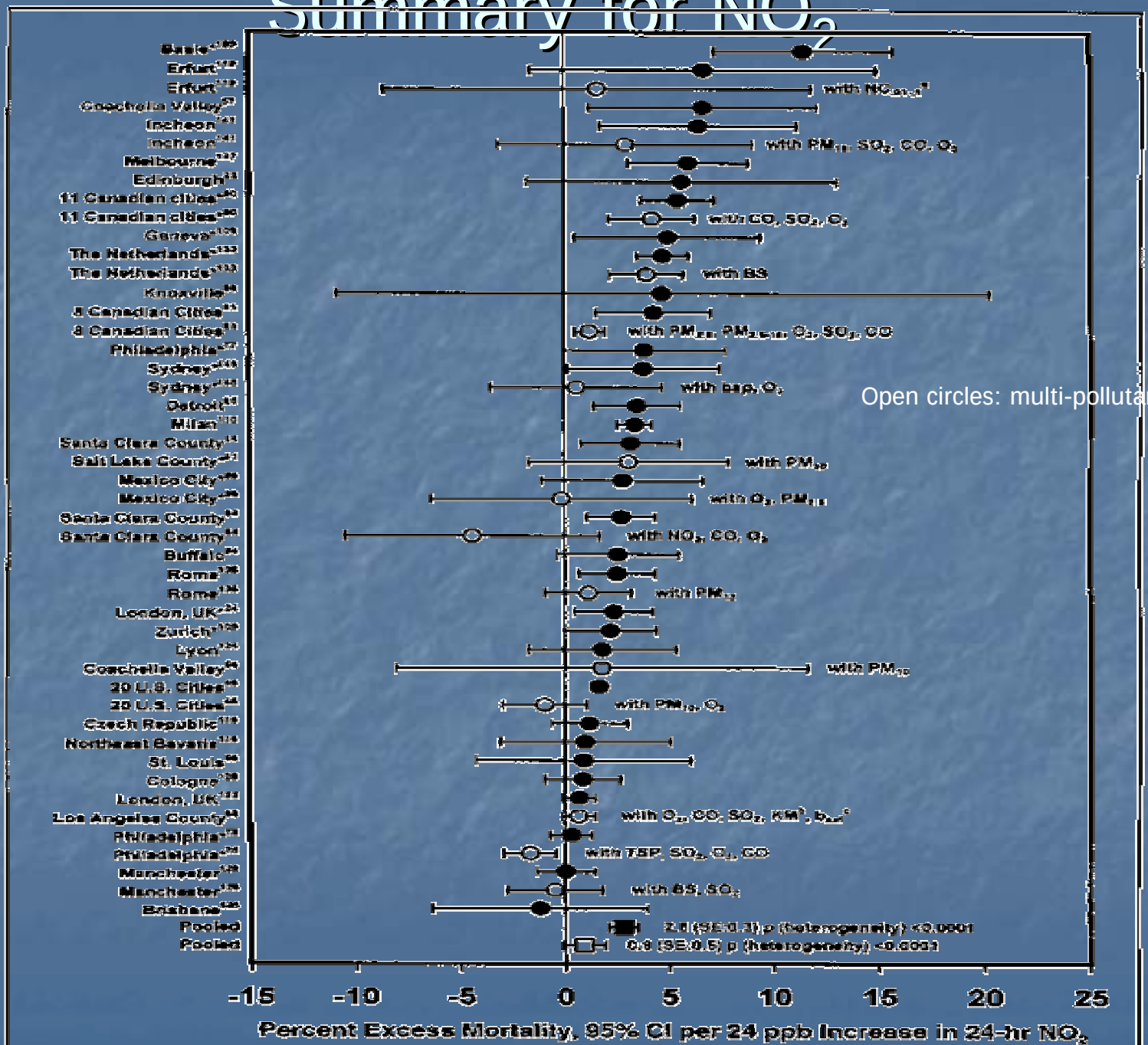
Effect of Pollution Episode on Mortality (London, England)



Summary for particles

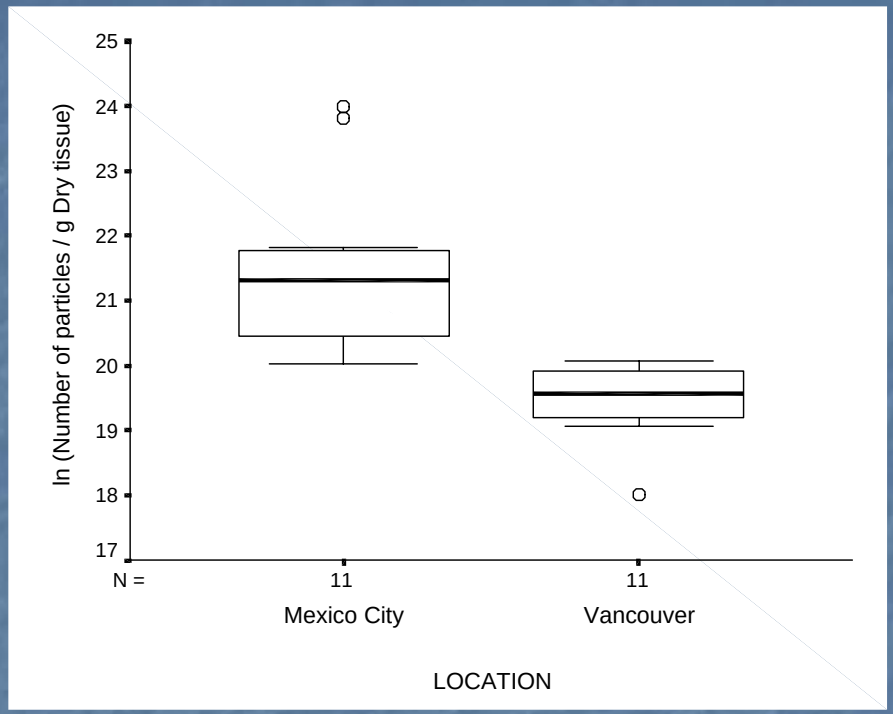


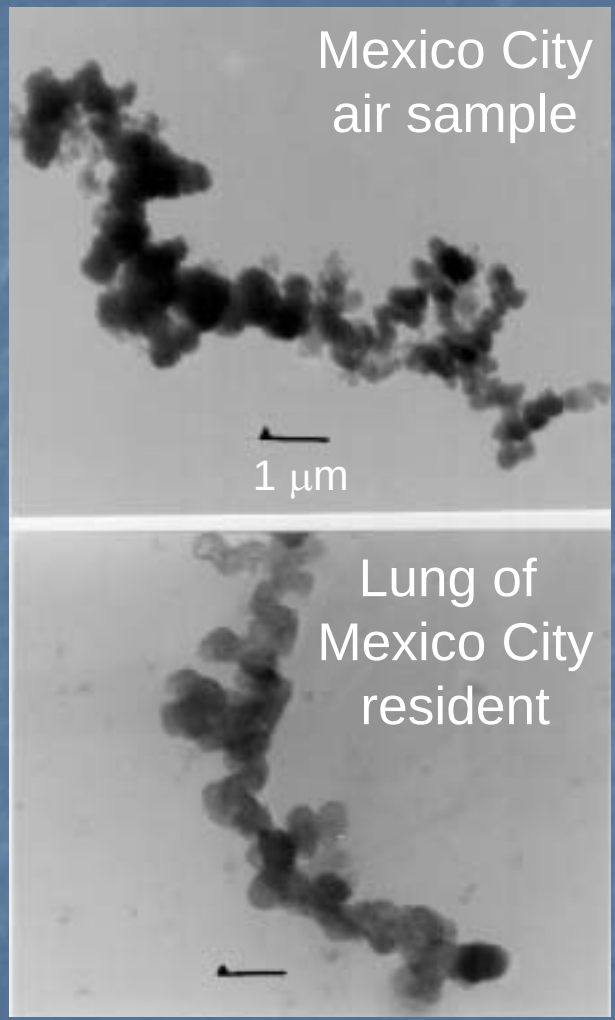
Summary for NO_2



Open circles: multi-pollutant models

Particle Retention in Human Lungs



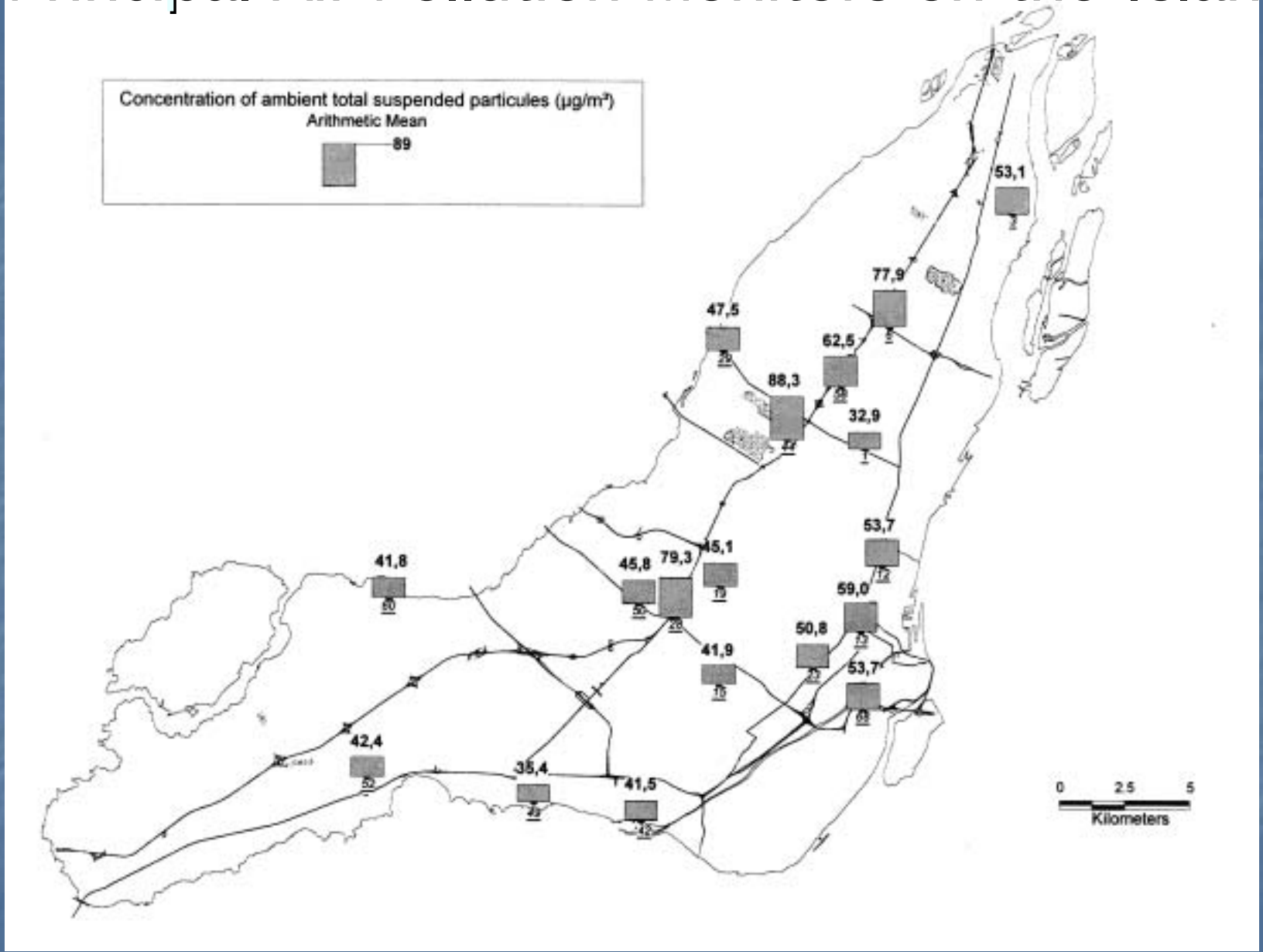


Data from Michael Brauer, U. of British Columbia.

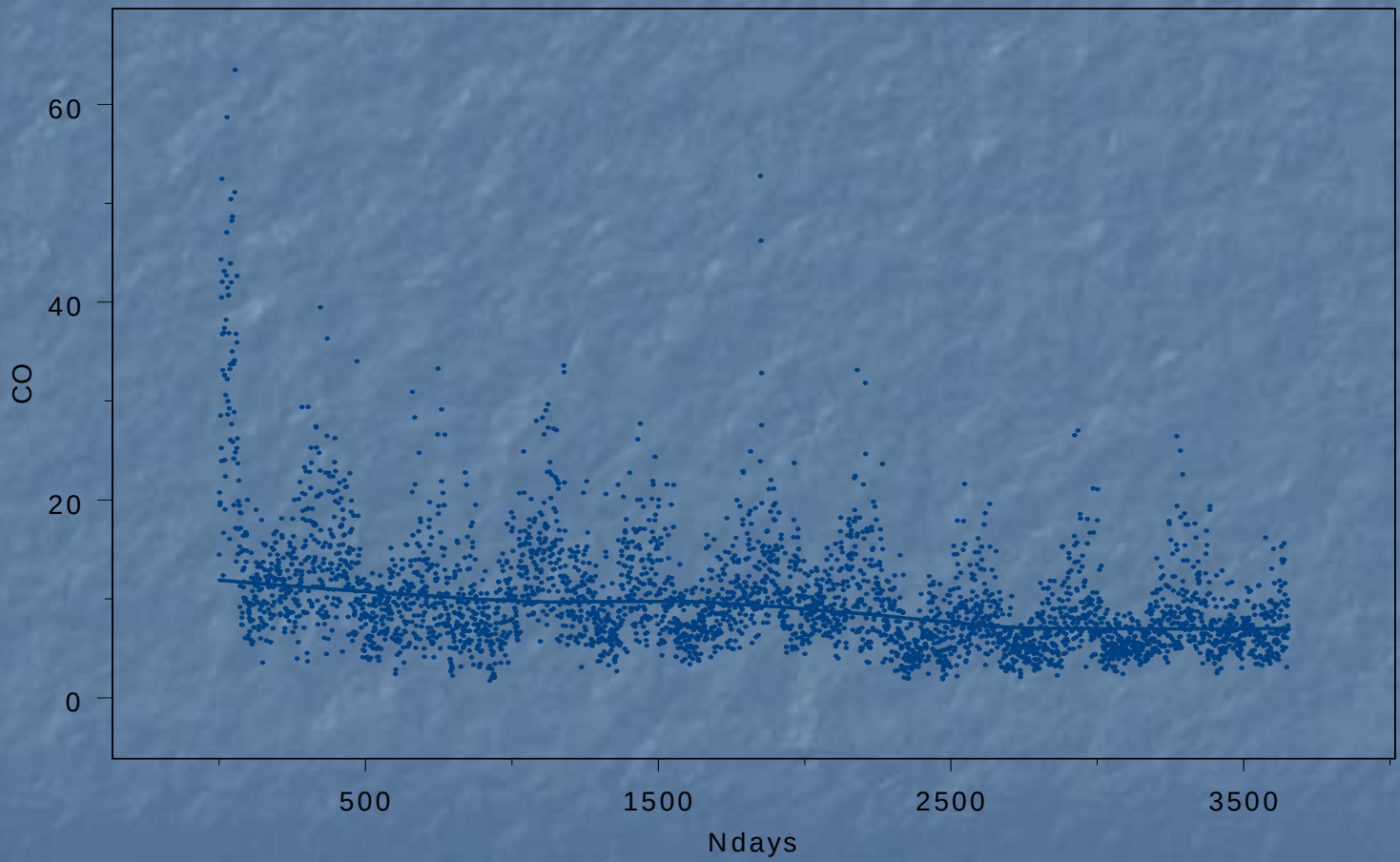
Short-term Effects: Who is at risk?

- Under pollution levels observed today, only persons with compromised physiologic systems should be at risk for short-term effects of air pollution.
- E.g.: cardio-pulmonary diseases, cancer

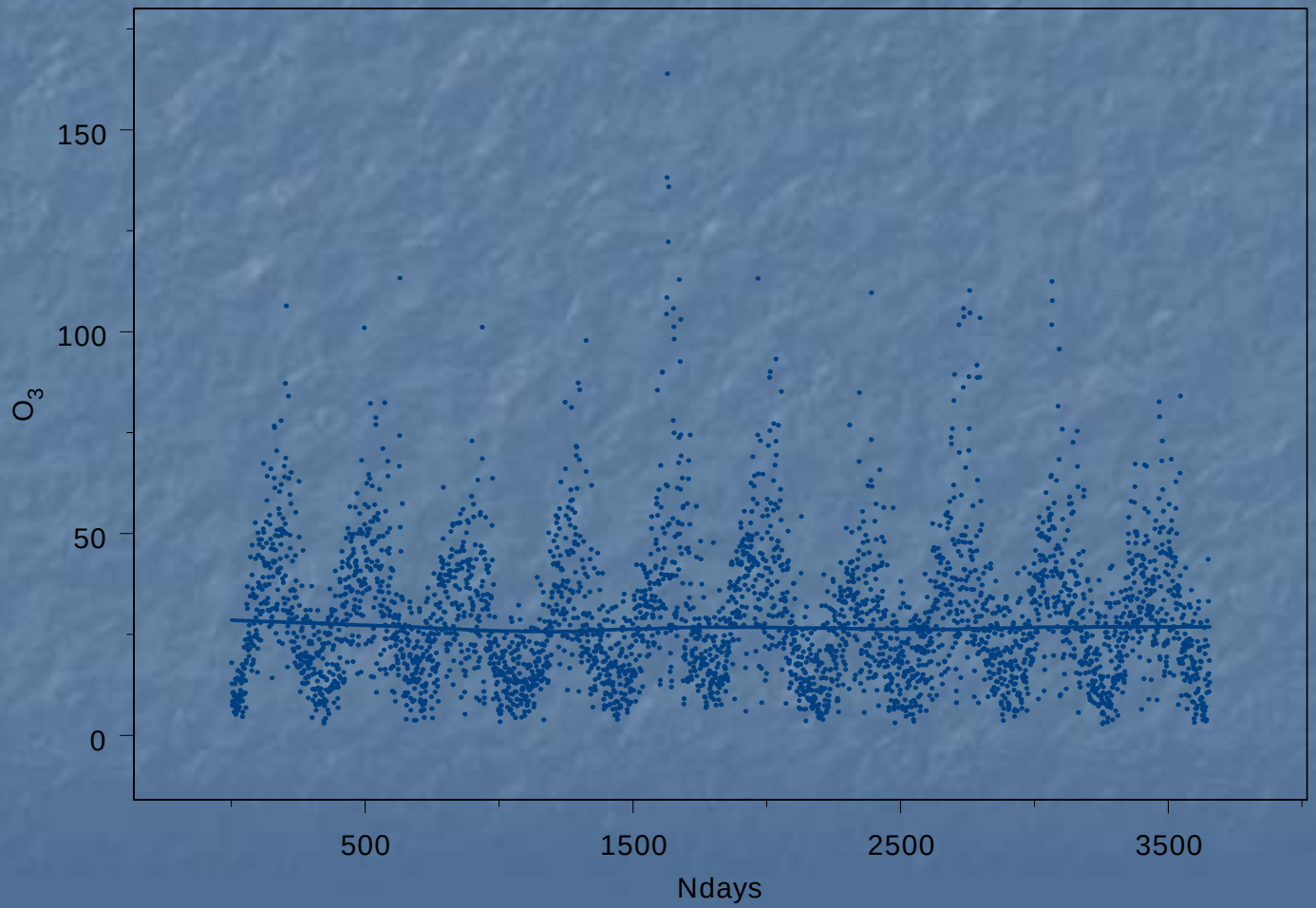
Principal Air Pollution Monitors on the Island



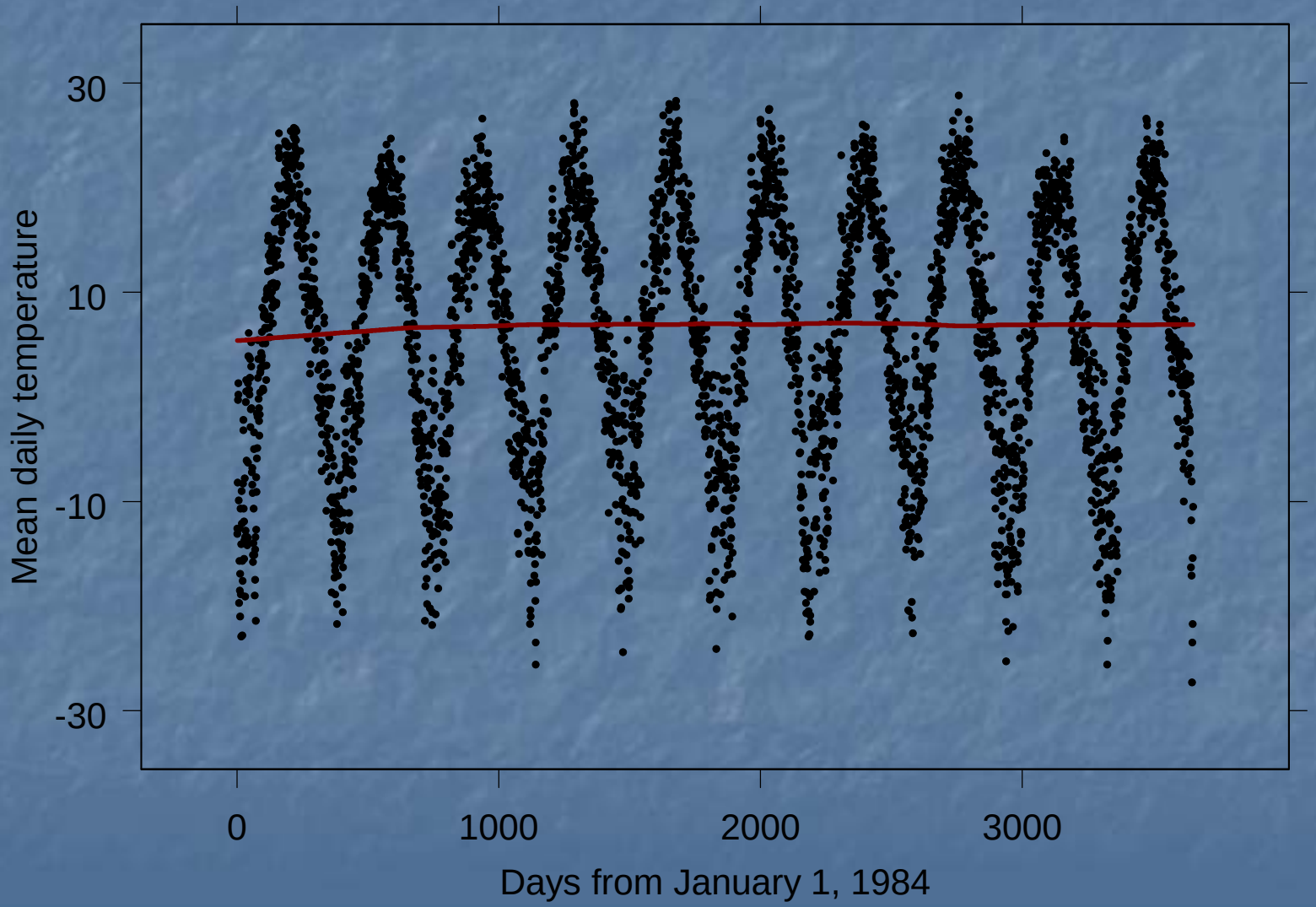
NO_2 in Montreal: 1984-1993



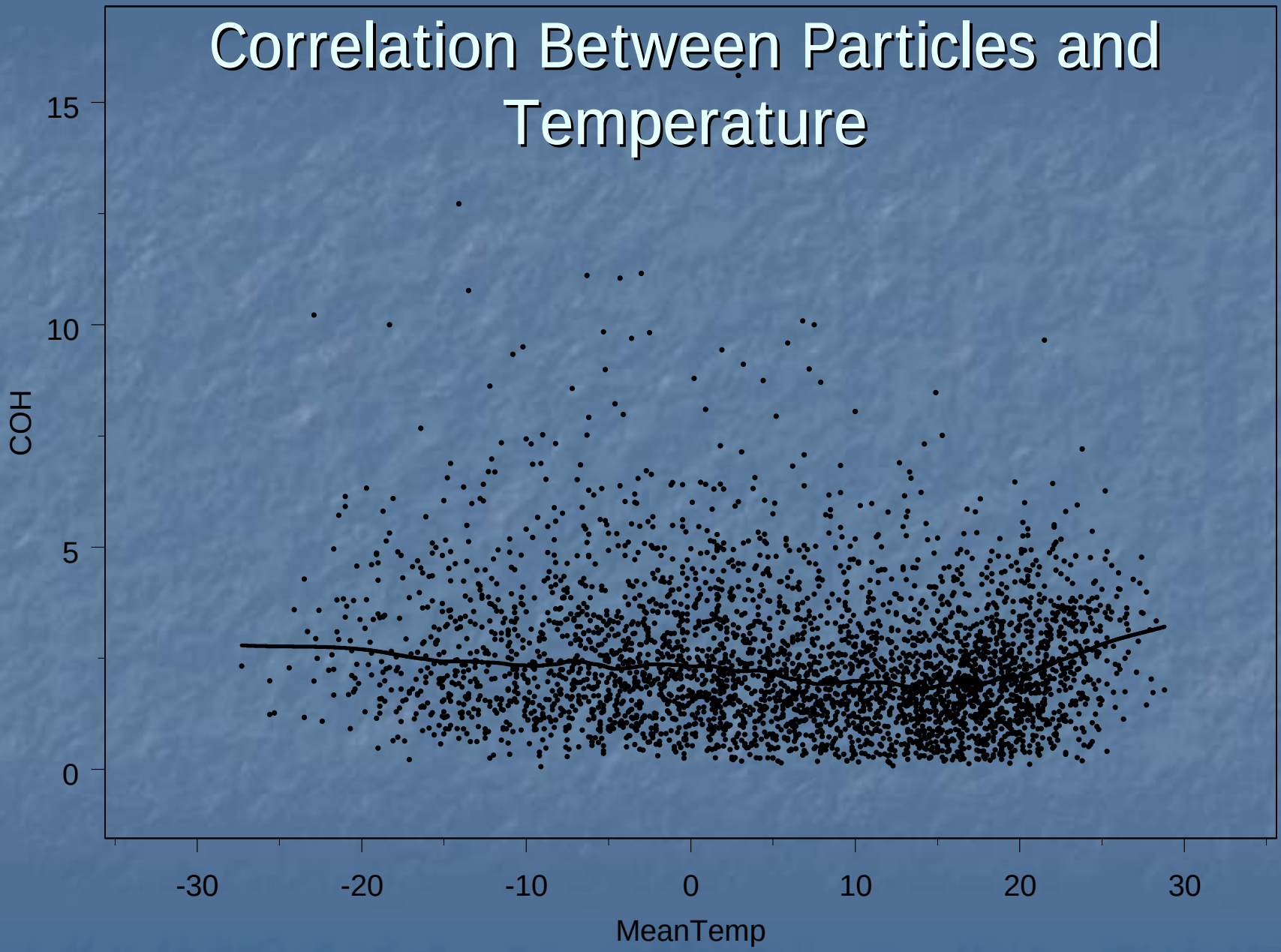
Ozone in Montreal: 1984-1993

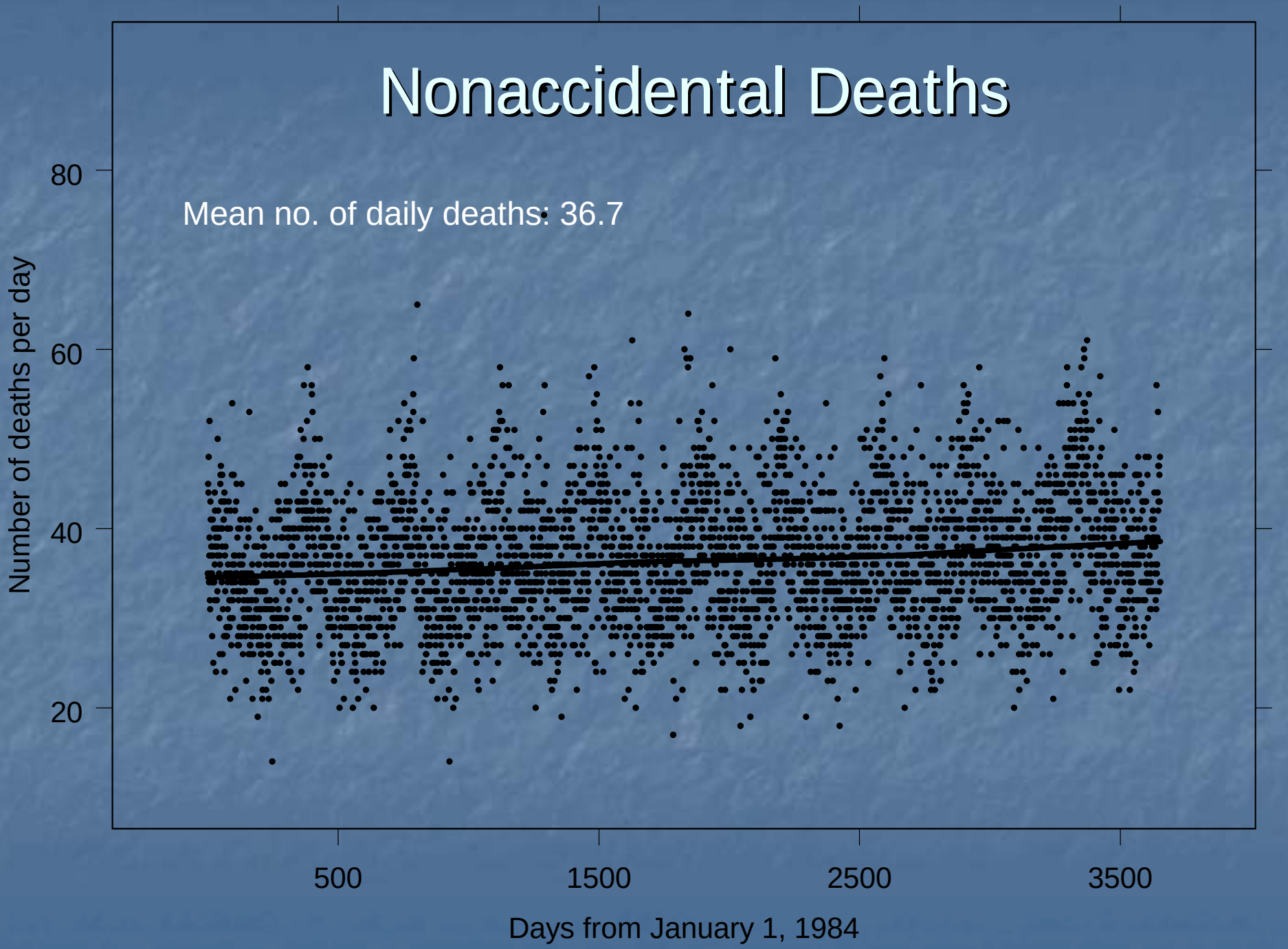


Time Series for Mean Temperature

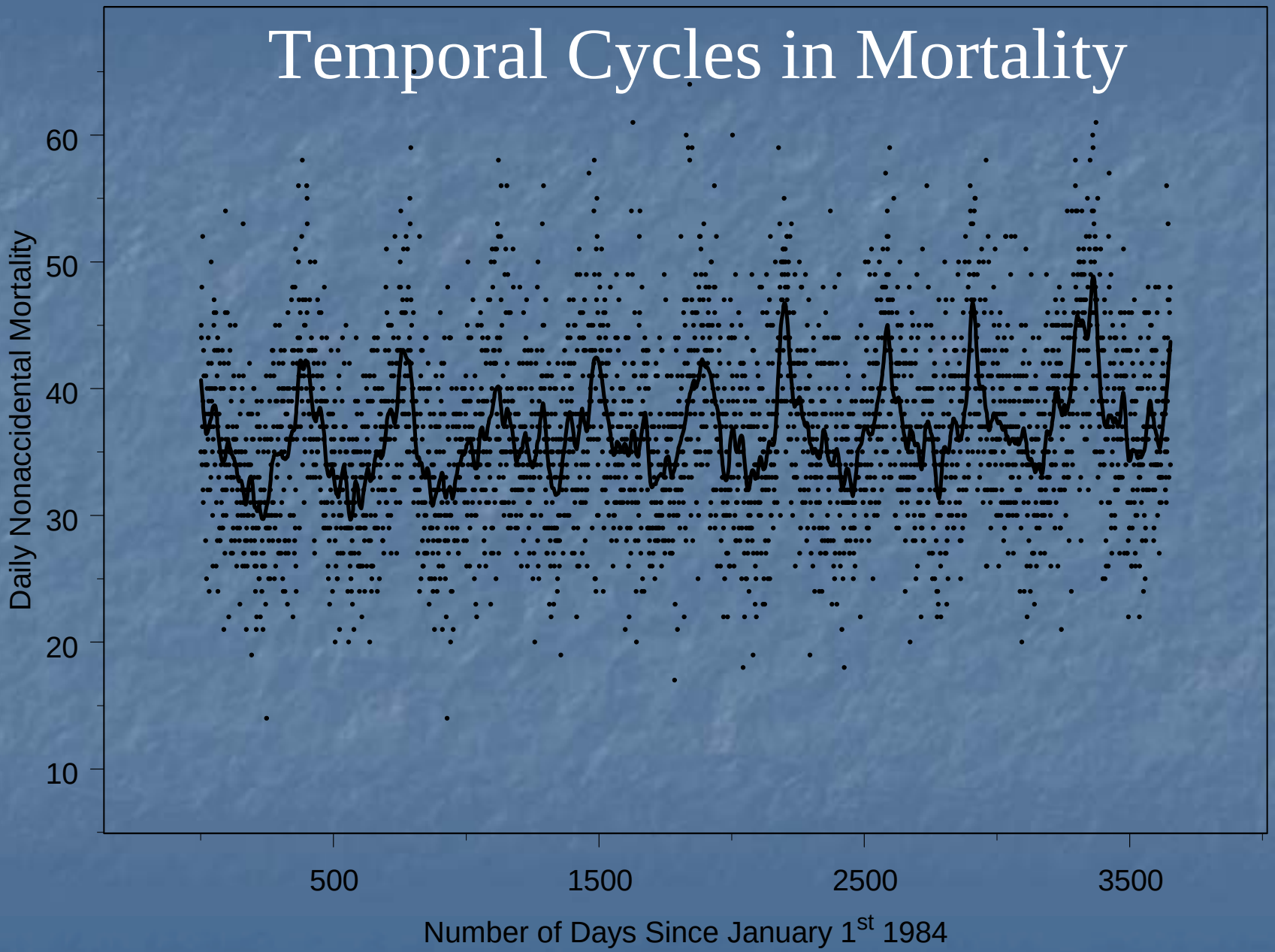


Correlation Between Particles and Temperature

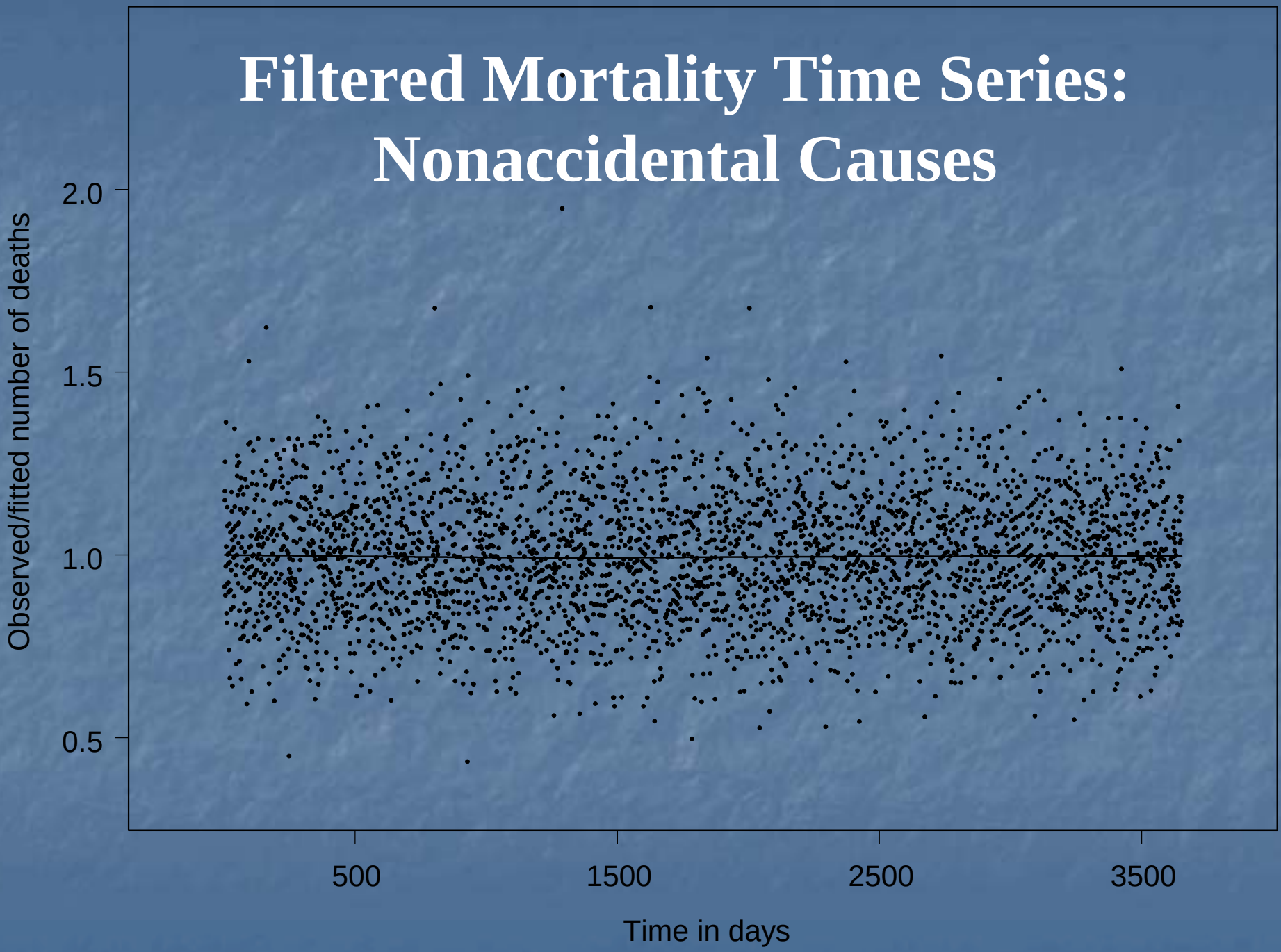



Nonaccidental Deaths
Mean no. of daily deaths: 36.7
Number of deaths per day
80
60
40
20
500
1500
2500
3500
Days from January 1, 1984

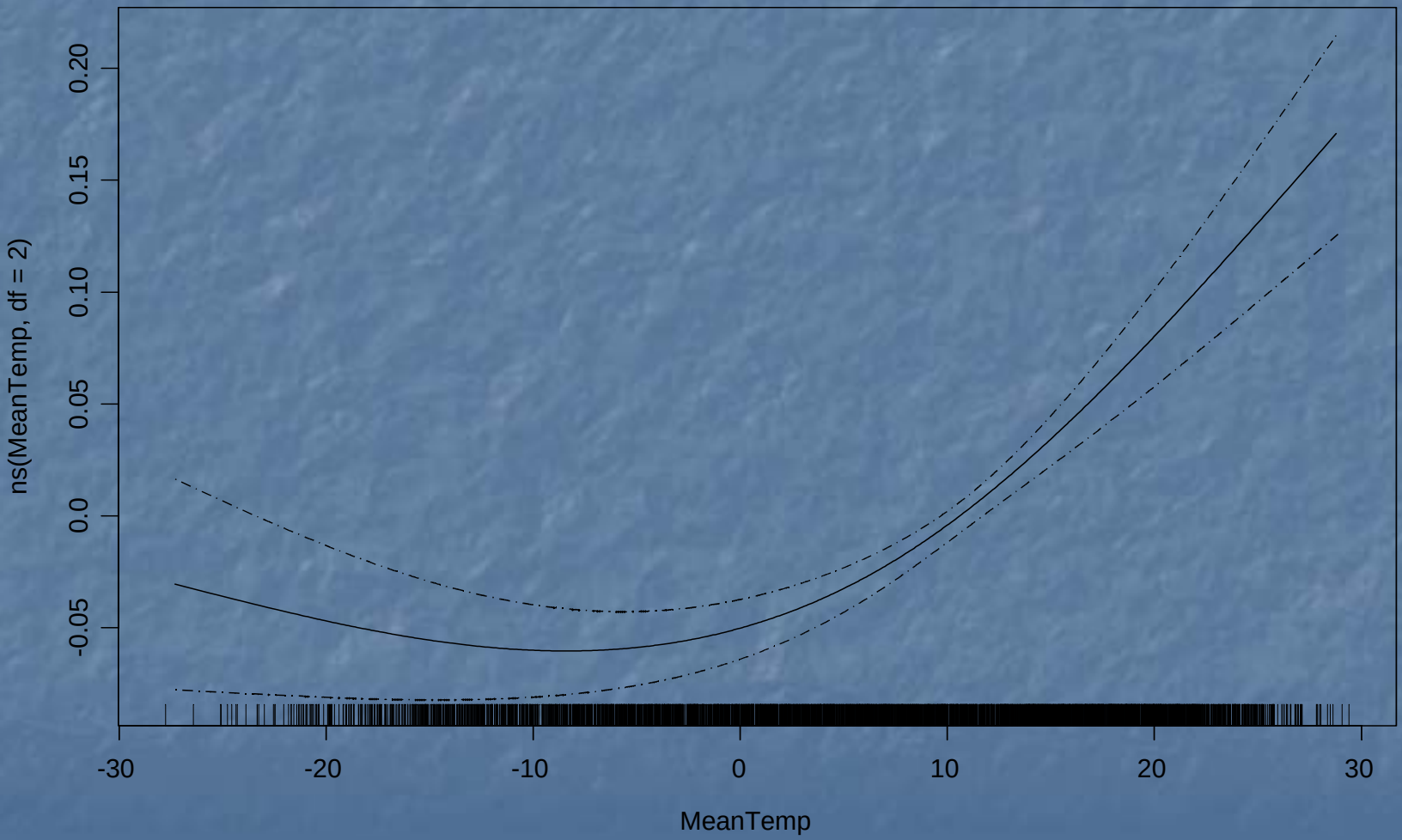
Temporal Cycles in Mortality



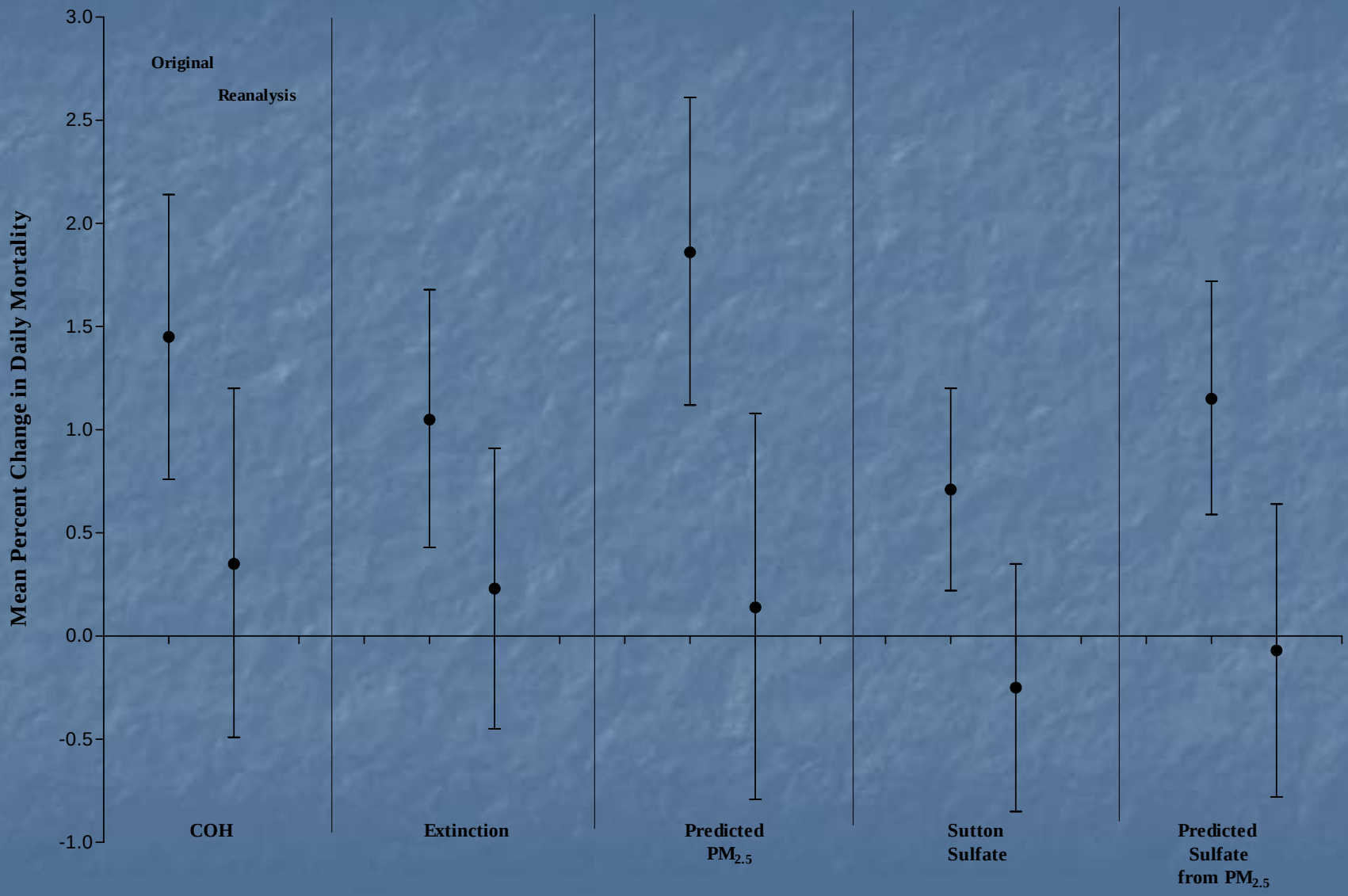
Filtered Mortality Time Series: Nonaccidental Causes



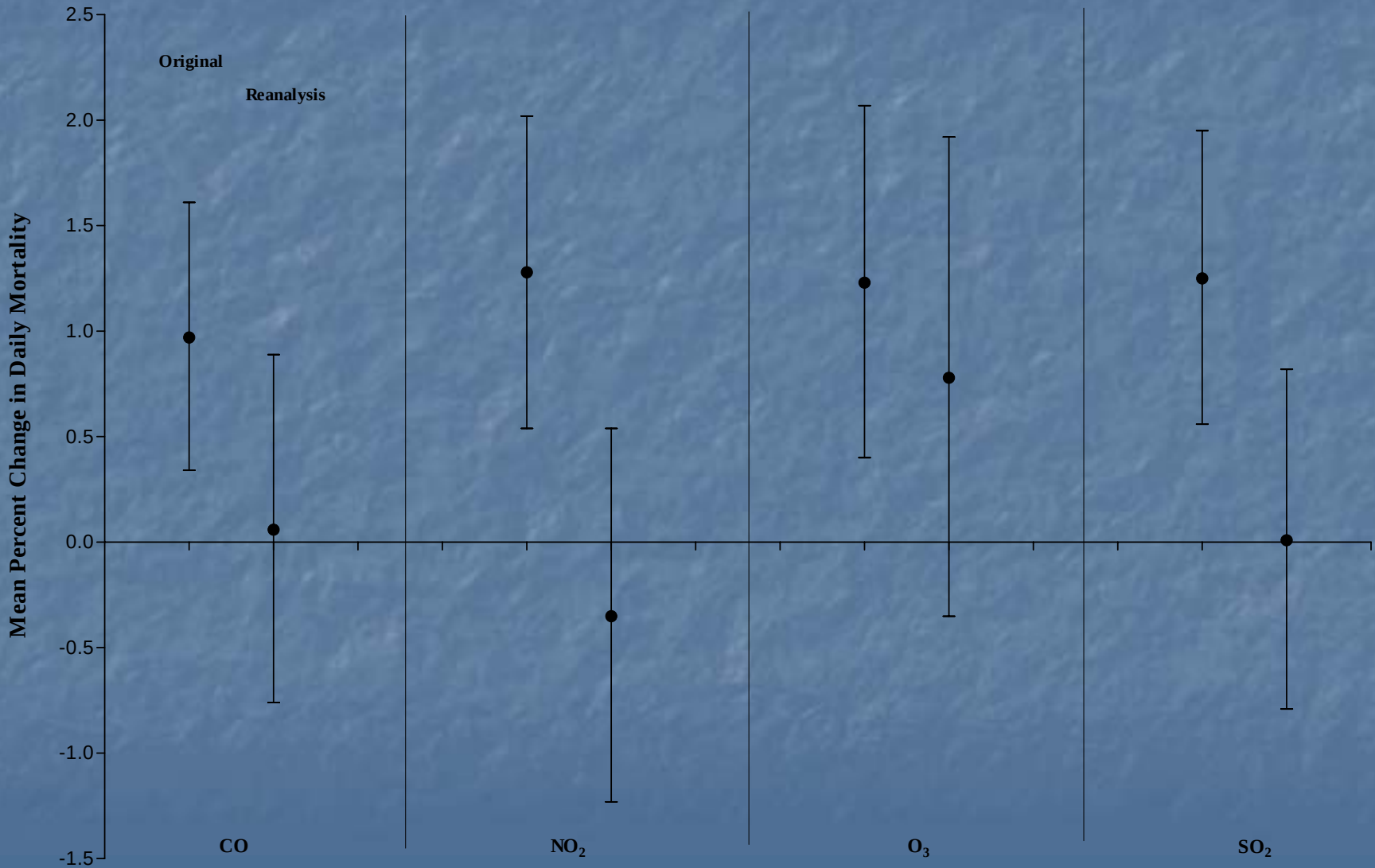
Relationship Between Daily Mortality and Mean Daily Temperature



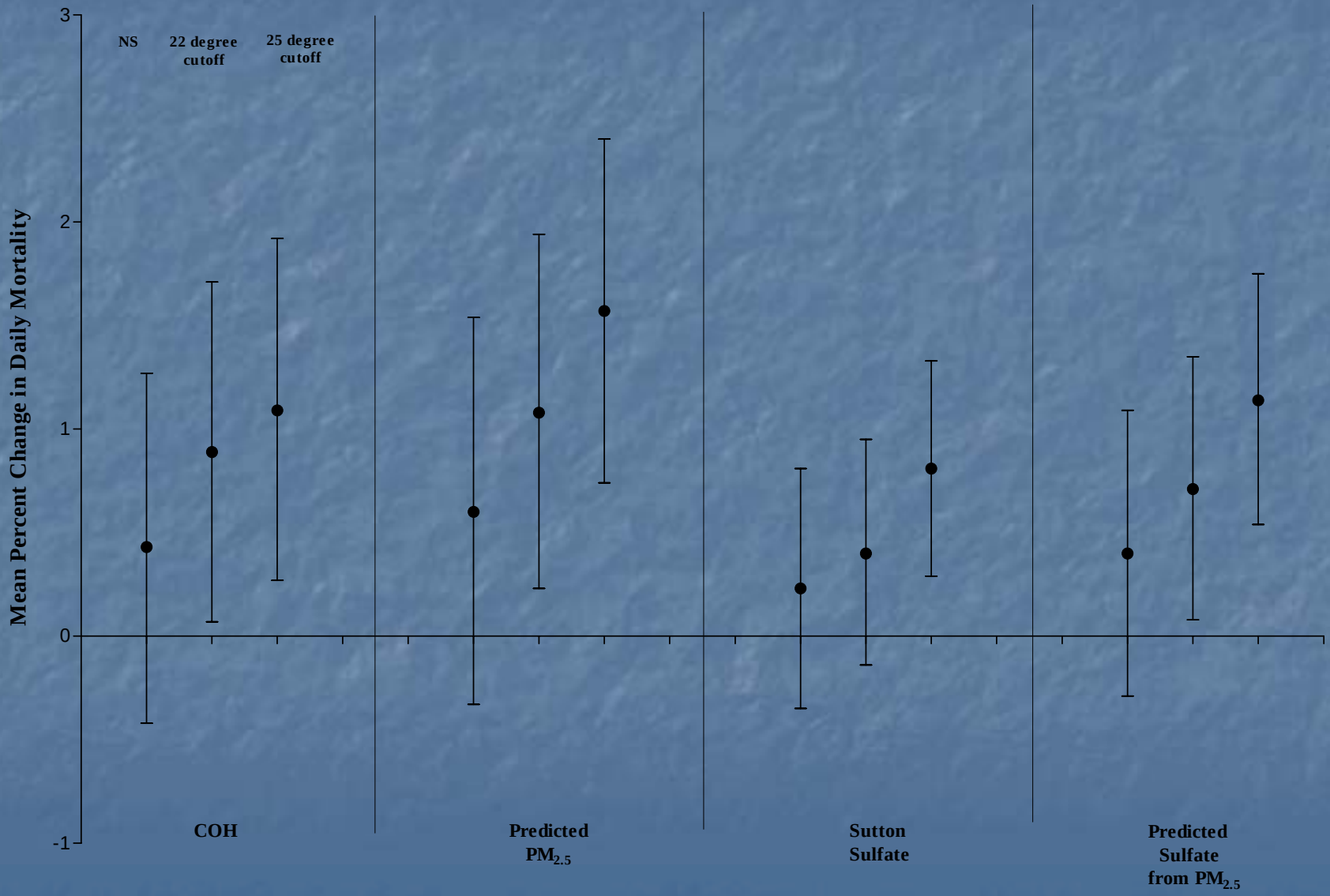
Original versus Reanalysis



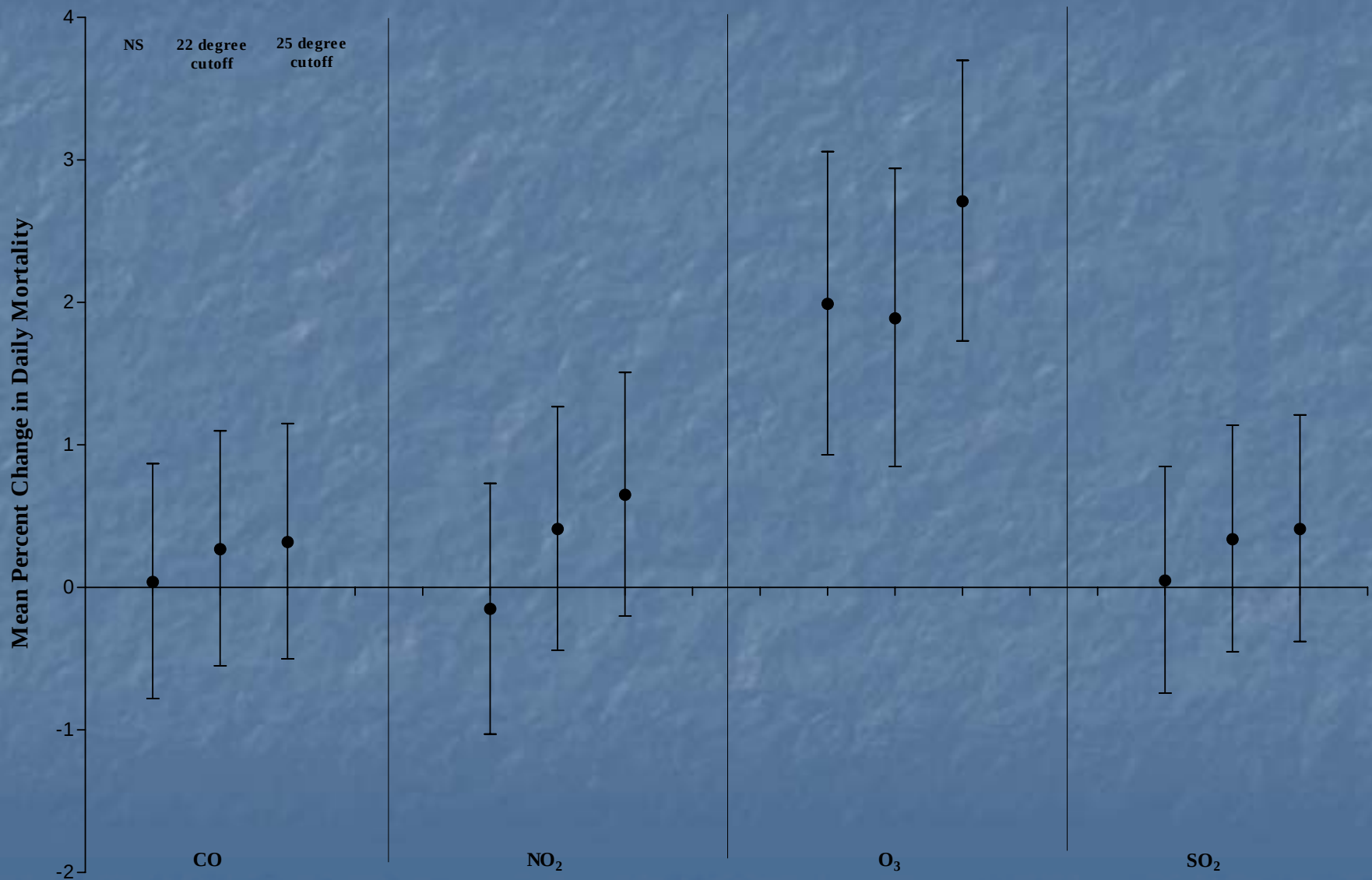
Original versus Reanalysis

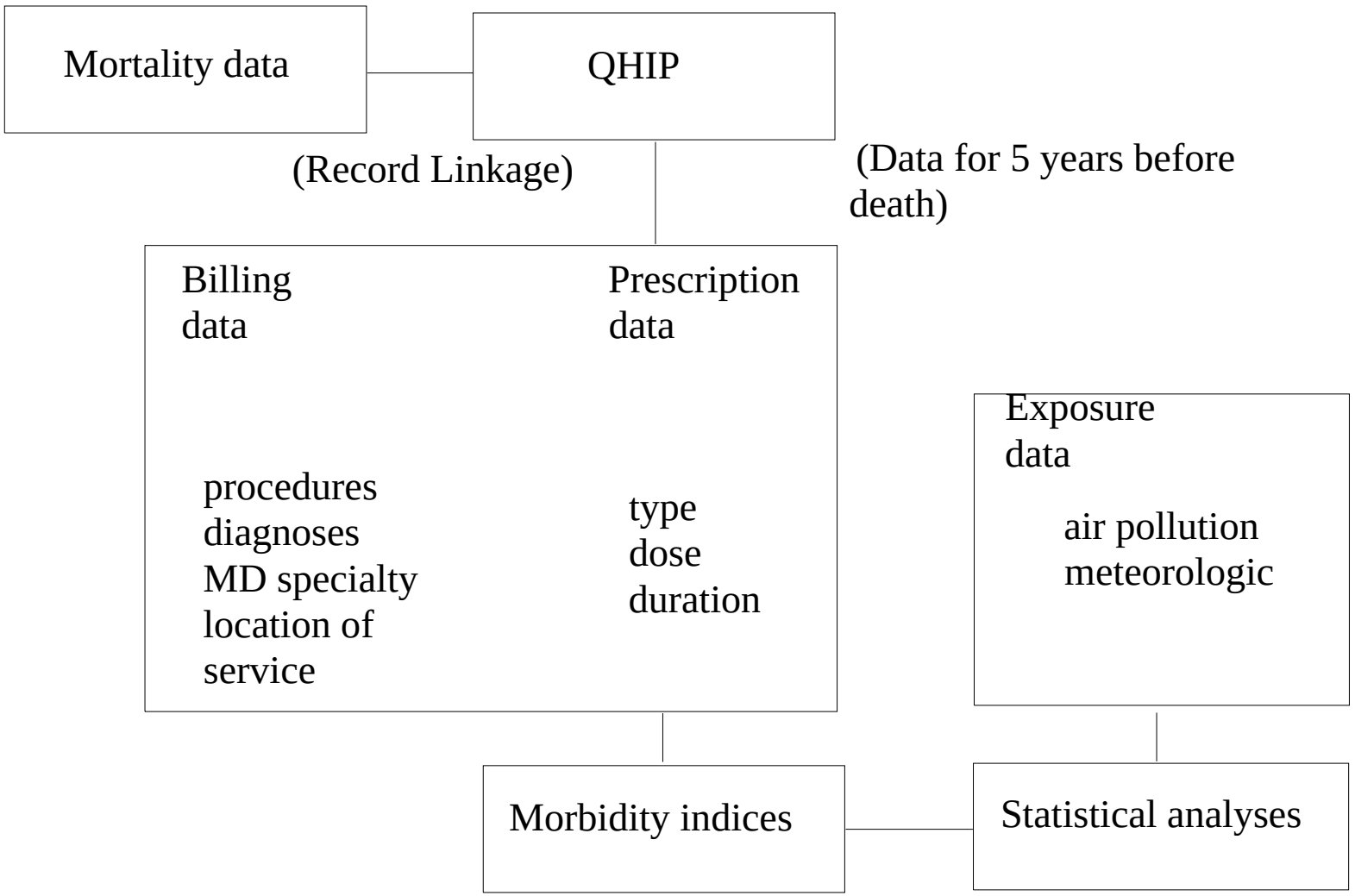


Reanalysis: Sensitivity to Temperature

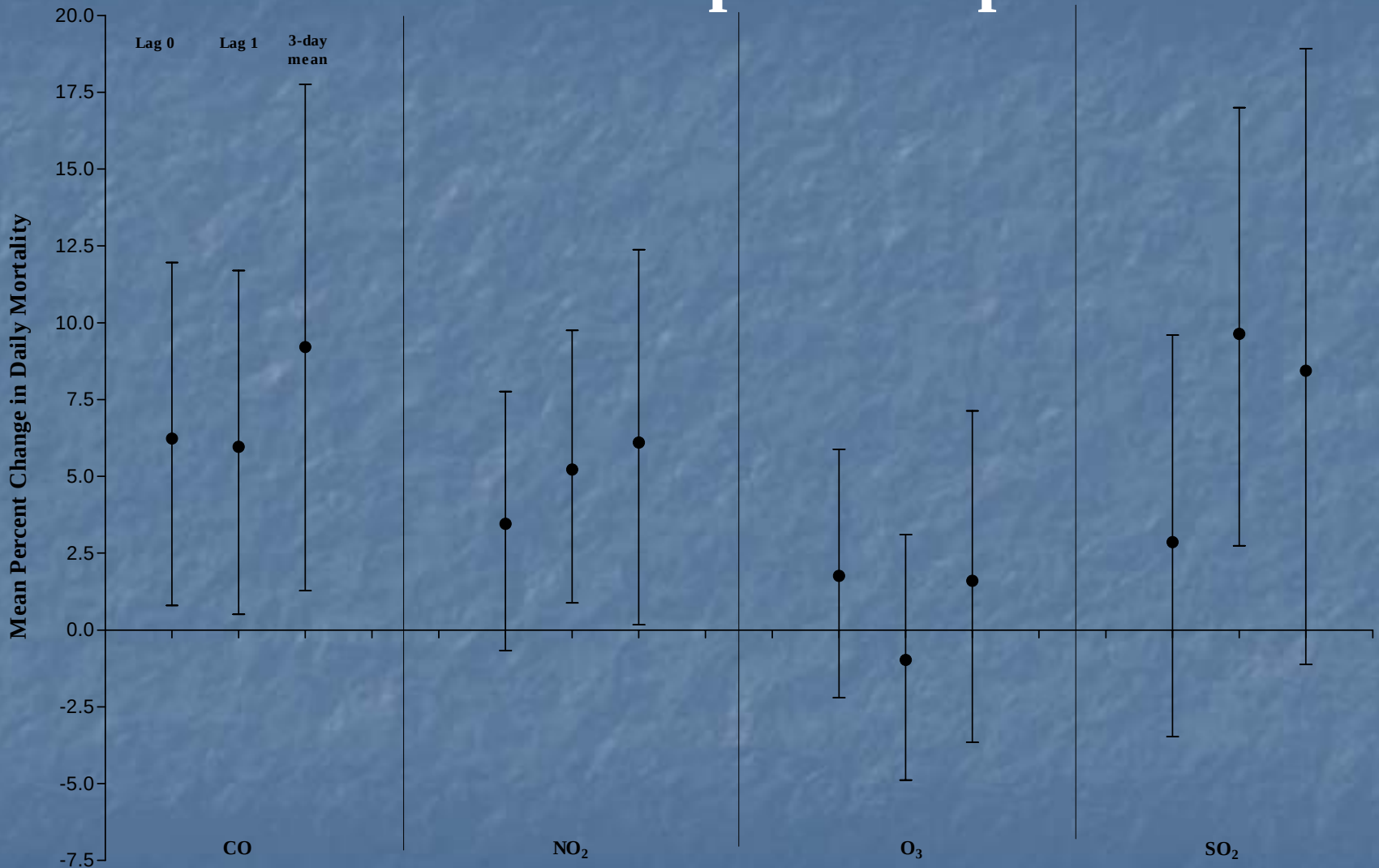


Reanalysis: Sensitivity to Temperature




Mortality data
QHIP
(Record Linkage)
(Data for 5 years before death)
Billing data
Prescription data
procedures
diagnoses
MD specialty
location of service
type
dose
duration
Exposure data
air pollution
meteorologic
Morbidity indices
Statistical analyses

Congestive Heart Failure
Warm Season - April to September



Panel Study of CHF

- **Objective:** to determine whether daily exacerbations in essential signs, symptoms, and physiologic indicators fluctuate with daily variations in concentrations of ambient air pollution

Design

- Daily diary of signs and symptoms
- Daily measurements of:
  - oxygen saturation, pulse rate
  - weight
  - blood pressure
- Hourly measurements of air pollutants and weather conditions
- 2-3 months duration per subject

- Physiologic parameters:
  - Weight, oxygen saturation, heart rate, blood pressure, swelling of ankle

MARKING INSTRUCTIONS

HB Pencil only

Correct Mark ●

Incorrect Marks ✓ ✗ ● ⊙

Centre universitaire de santé McGill
McGill University Health Centre

McGill University Heart Failure Study
DAILY DIARY

Date:
Month Day

Patient ID:

1. Please record your weight: ○ kg or ○ lbs
2. Please record your temperature: (°C)
3. Using the pulse oximeter, please record your oxygen saturation:
4. Using the pulse oximeter, please record your pulse rate (resting):
5. Using the electronic blood pressure gauge, please record your blood pressure: Systolic / Diastolic
6. How many pillows did you use last night when you slept?

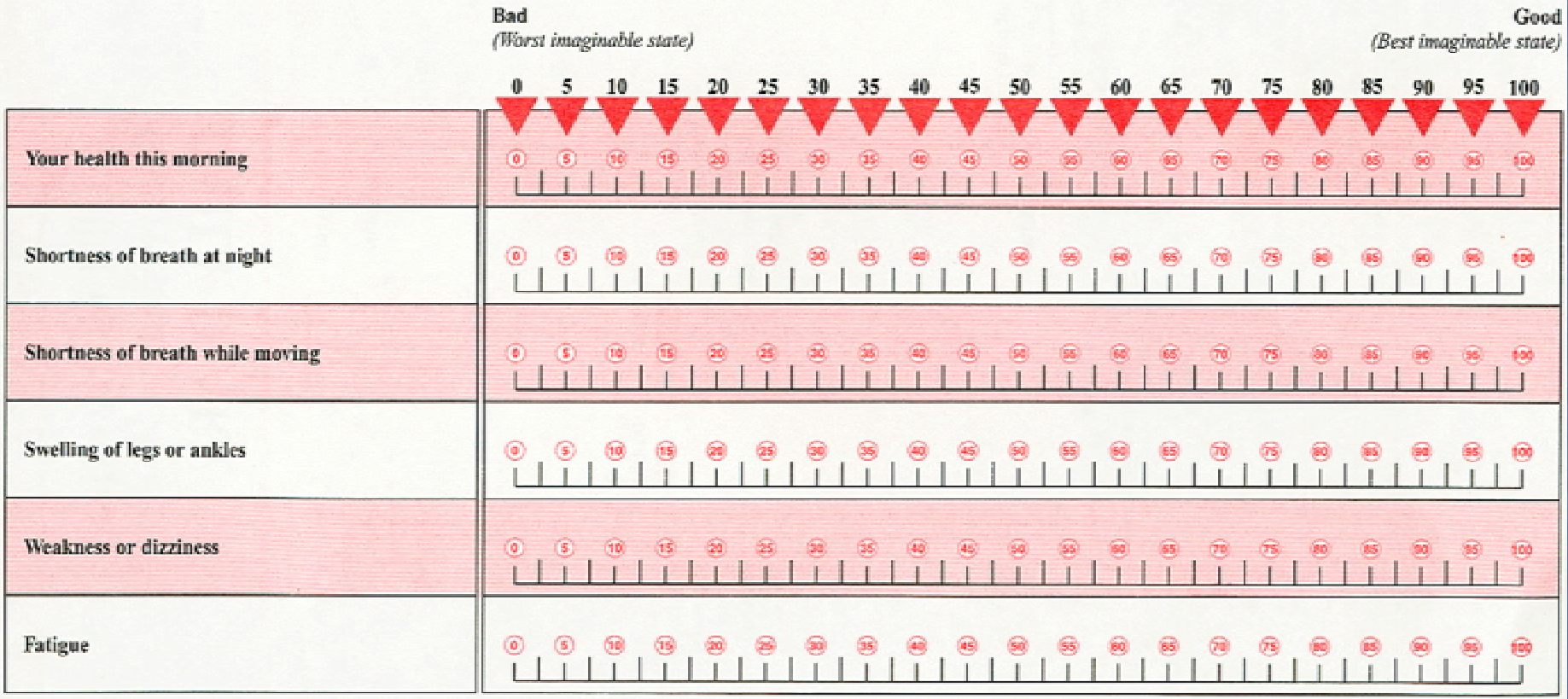
7.	Did you have any joint pain yesterday?	○ No	○ Yes
8.	Did you have a runny nose or sore throat yesterday?	○ No	○ Yes
9.	Did you have a cough yesterday?	○ No	○ Yes
10.	Were you taking antibiotics yesterday?	○ No	○ Yes
11.	Did you add salt to any of your meals yesterday? *(If NO, go to #12)*	○ No	○ Yes
	For how many meals?	① ② ③	

12. How many cups of liquid did you drink yesterday?

13. Did you eat any of the following foods yesterday?

Prepackaged soups	○ No	○ Yes
Sauces: chilli, HP, soya, VH, Worcestershire, ordinary ketchup	○ No	○ Yes
Pickled foods (e.g., olives, pickles)	○ No	○ Yes
Canned foods (e.g., sardines, baked beans)	○ No	○ Yes
Salted crackers (e.g., Ritz)	○ No	○ Yes
Antacids (e.g., Bromo Seltzer)	○ No	○ Yes
Chips, pretzels, salted nuts, etc...	○ No	○ Yes
Cold cuts (e.g., pepperoni, ham, smoked meat, bacon)	○ No	○ Yes
Fish	○ No	○ Yes
Mineral water containing salt	○ No	○ Yes
Frozen dinners	○ No	○ Yes
Breaded foods	○ No	○ Yes
Salted butter, margarine, peanut butter	○ No	○ Yes
Store-bought salad dressings	○ No	○ Yes

To help people say how good or bad their health is, we have drawn a scale (rather like a thermometer) on which we would like you to rate six aspects of your health. The best imaginable state is 100 and the worst imaginable state is 0. We would like you to place a mark on each scale to indicate how good or bad your health is today. This mark corresponds to your opinion of your health.



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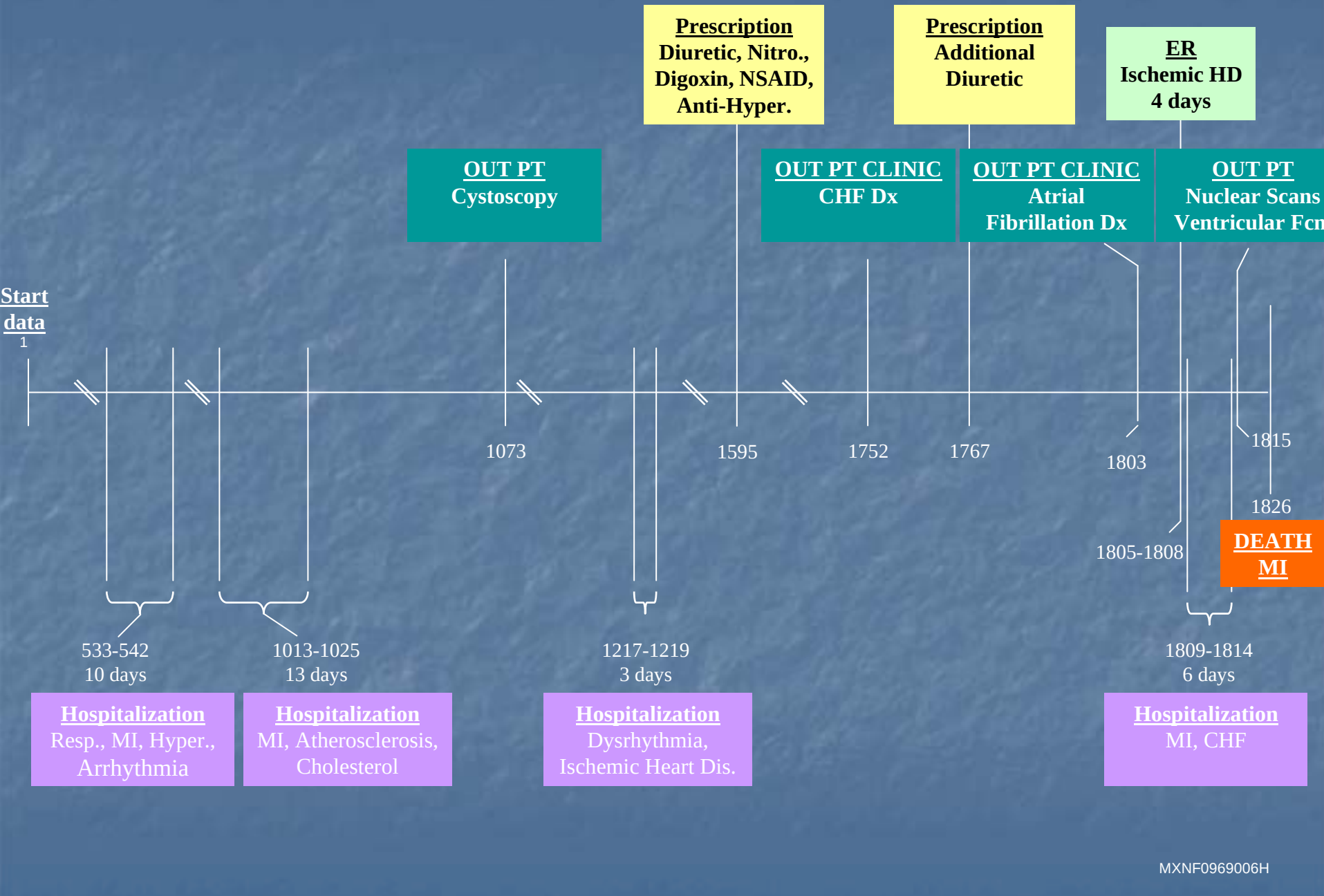
Longitudinal Study of Air Pollution

Motivation

- Analytic issues associated with time series studies (statistical models, confounding)
- Other designs needed that account for:
  - Personal risk factors (e.g., comorbidity)
  - Time-varying covariates
  - Recurrent events and multiple endpoints

Male Patient Age 65-69 Years at Time of Death



MXNF0969006H

Model for Change of Health State in CHF

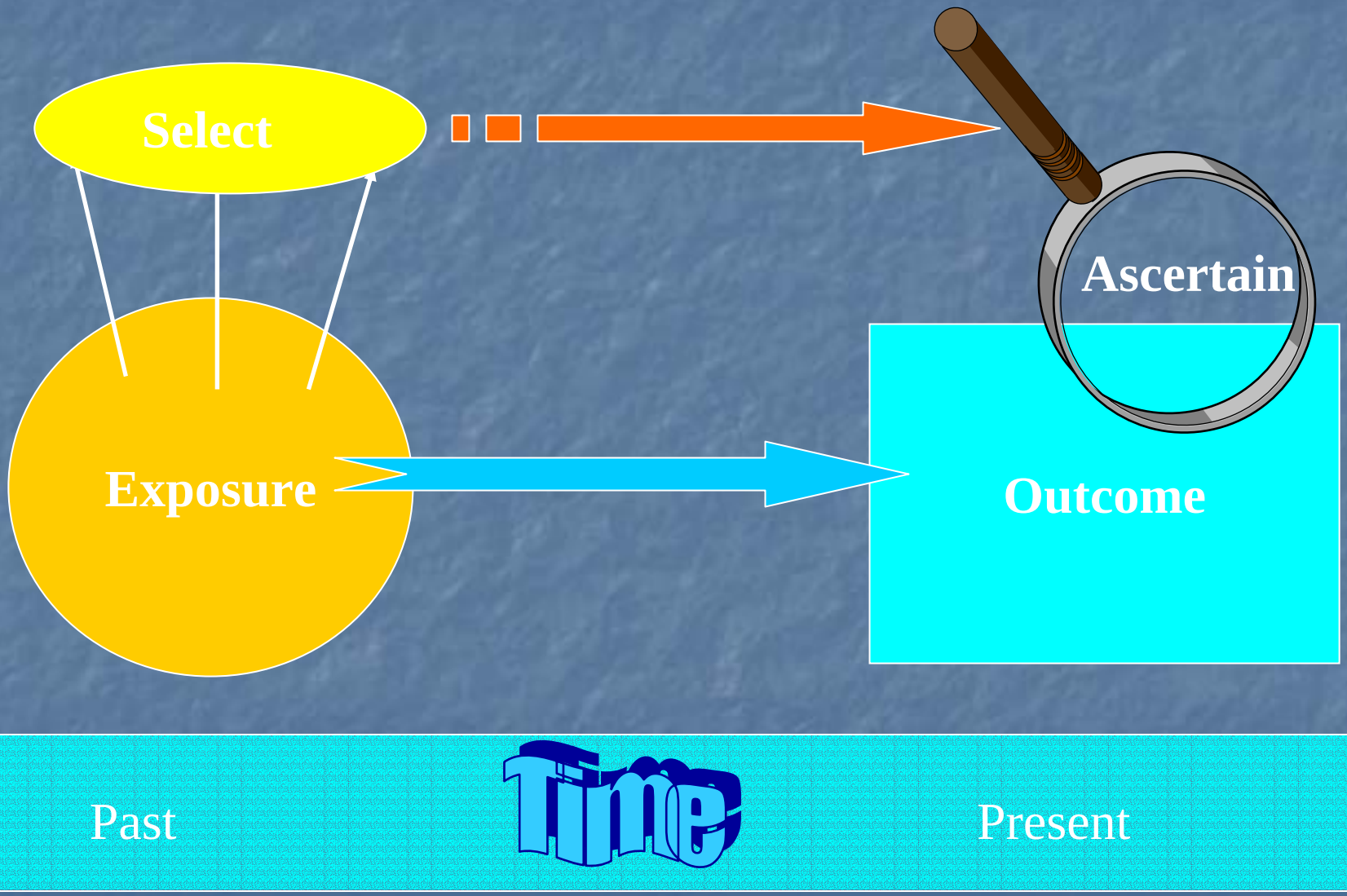
Health state	Definition
Newly diagnosed	First diagnoses and tests; no medication
First treated	First prescription for a diuretic
Decline in condition	Increase in dose of the diuretic
Decline in condition	Change to a more potent diuretic
Decline in condition	Change to a combination of diuretics
Decline in condition	Increase in dose of the diuretics
Acute exacerbation-mild	Emergency room or unscheduled outpatient clinic visit for decompensated heart failure/sequela

Acute exacerbation-mild	Emergency room or unscheduled outpatient clinic visit for decompensated heart failure/sequela
Acute exacerbation-moderate	Short-term hospitalization (≤3 days) for decompensated heart failure/sequela
Acute exacerbation-serious	Long-term hospitalization (3-10 days) for decompensated heart failure/sequela
Serious decline-endstage heart failure	Long-term hospitalization (>10 days) for decompensated heart failure/sequela
Serious decline-endstage heart failure	Unscheduled procedure-heart transplant

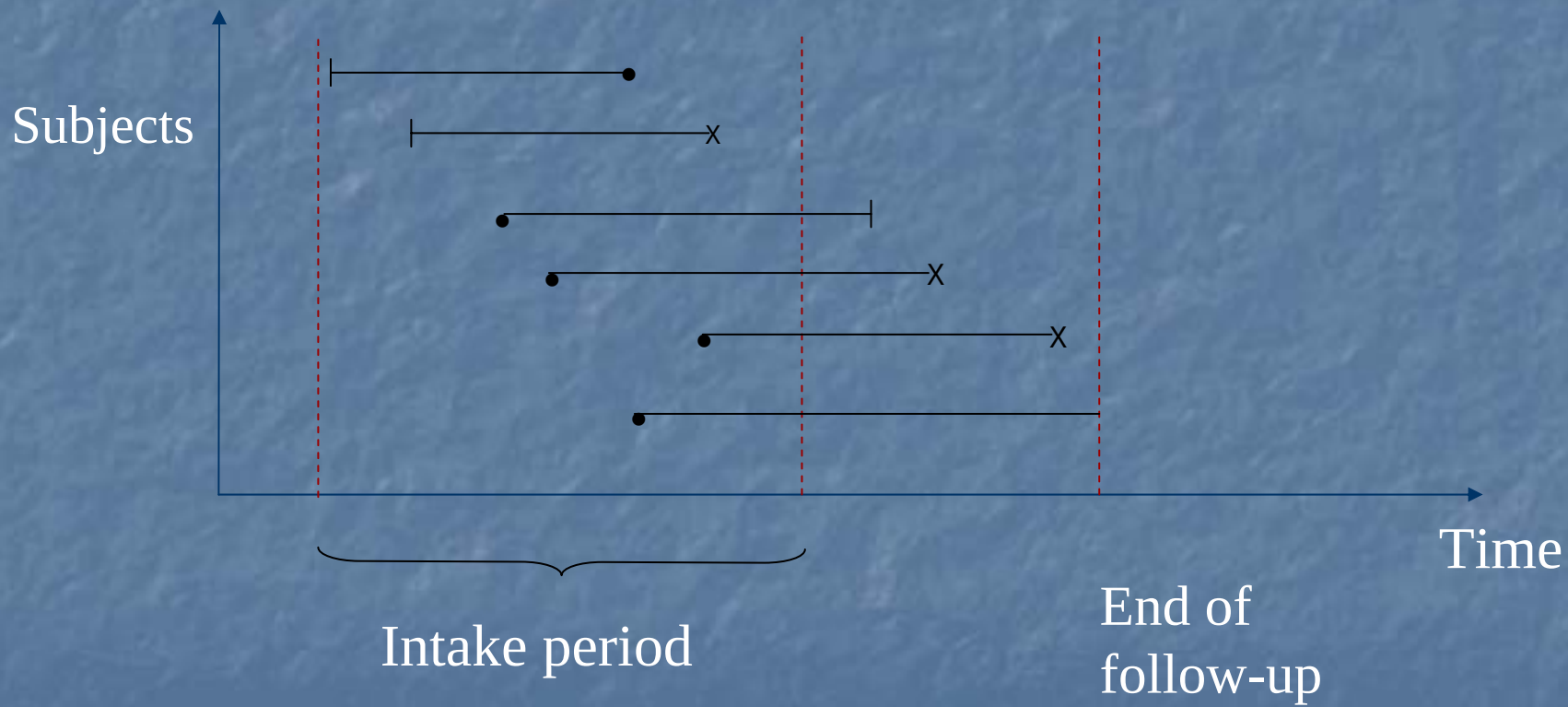
Long-Term Effects

- Question:
  - Does the rate of adverse health events (e.g., lung cancer incidence) increase with past exposures to air pollution?

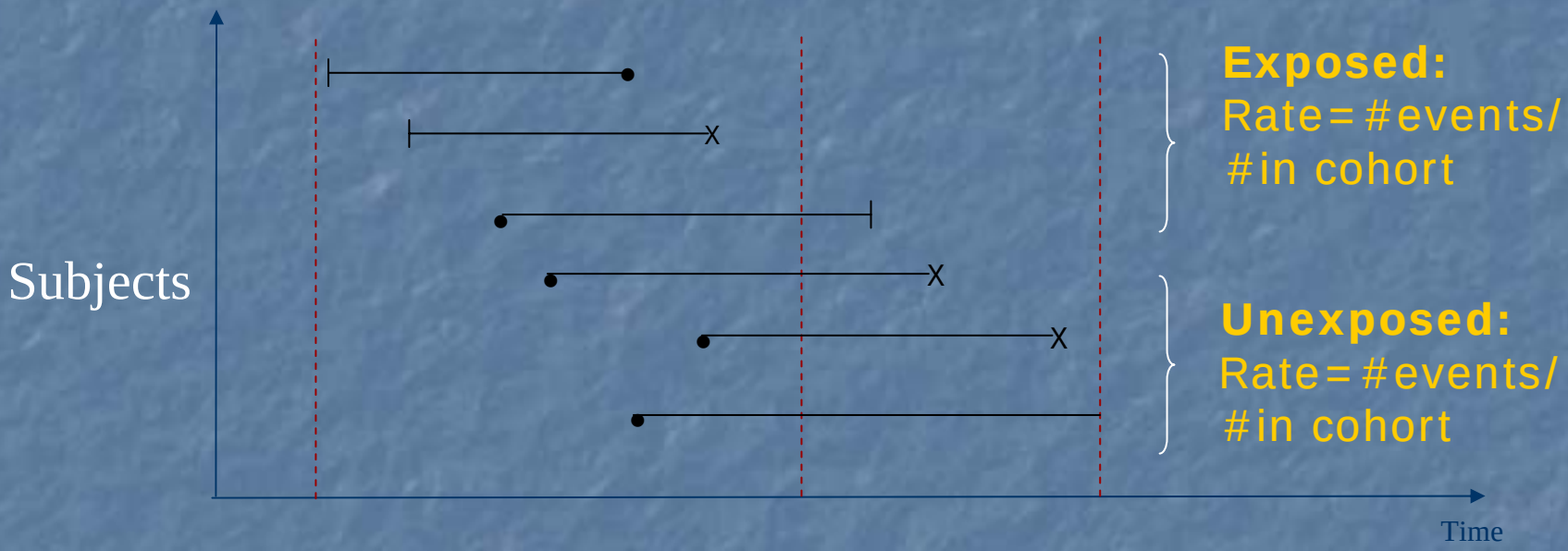
Cohort Studies



Cohort Studies



Measure of Association



Relative risk=rate(exposed)/rate(unexposed)

Cohort Studies

- The Harvard Six-cities Study
- The American Cancer Society Study
- California Adventist Health Study of Smog
- Netherlands Study of Diet and Health

Harvard Six-Cities Study: Levels of particles in the early 1980s

	Fine particles ($\mu g/m^3$)
Portage (WI)	11.0
Topeka (KS)	12.5
Watertown (MA)	14.9
St. Louis (MO)	19.0
Harriman (TN)	20.8
Steubenville (OH)	29.6

Montreal- 1980s: 20 $\mu g/m^3$; 1990s: 15 $\mu g/m^3$

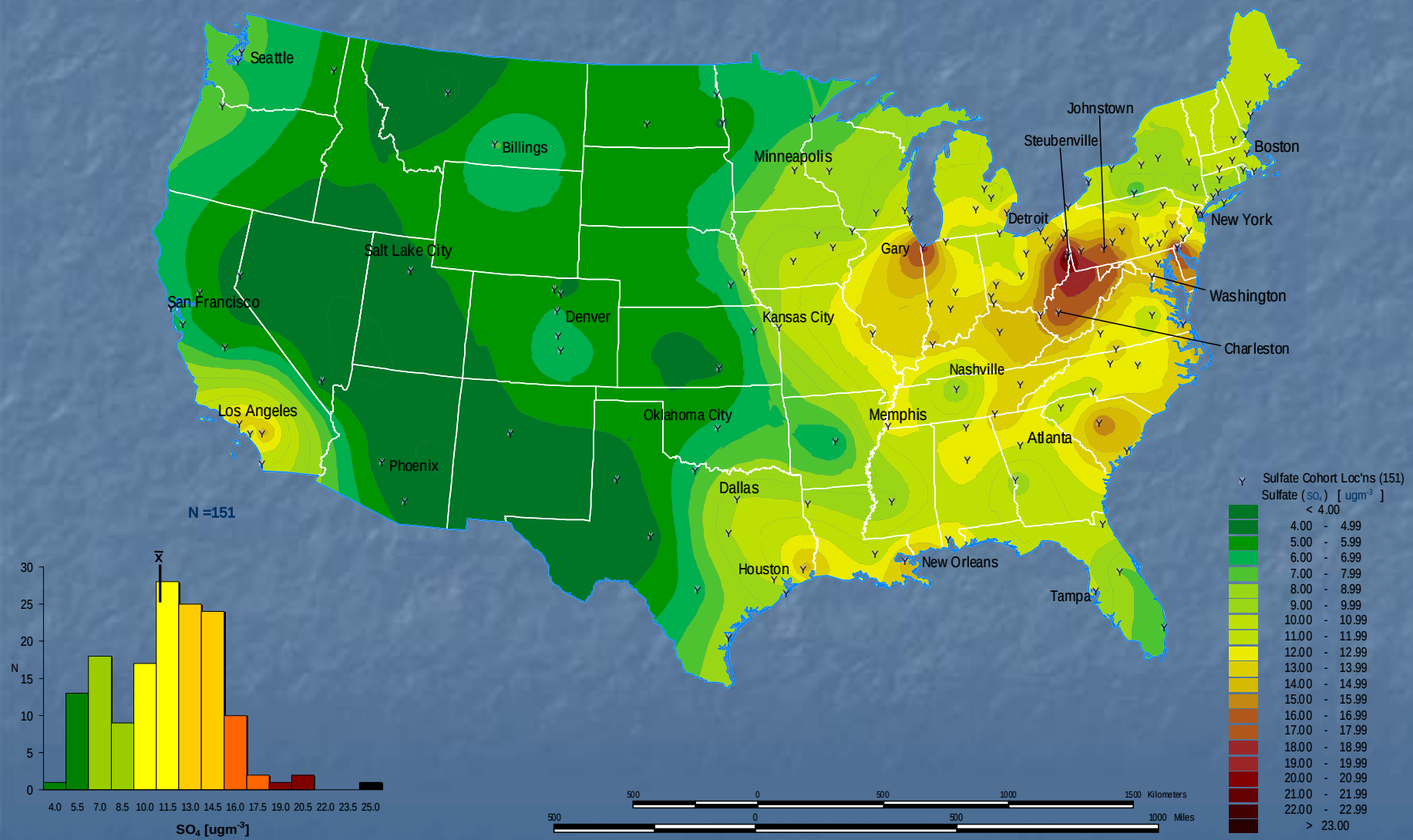
The Harvard Six-cities Study: Fine Particles (From Reanalysis)

Mortality from:	Relative Risk (95% CI) for a 20 μg/m^3 increase	RR for a 10 μg/m^3 increase
All causes	1.28 (1.10-1.48)	1.13
Cardiopulmonary	1.38 (1.12-1.69)	1.18
Lung cancer	1.43 (0.85-2.41)	1.20
Other causes	1.01 (0.79-1.30)	1.01

Krewski et al. 2000 Health Effects Institute Report (Boston)

The American Cancer Society Study

Modeled (Kriged) Sulfate (SO_4) Surface

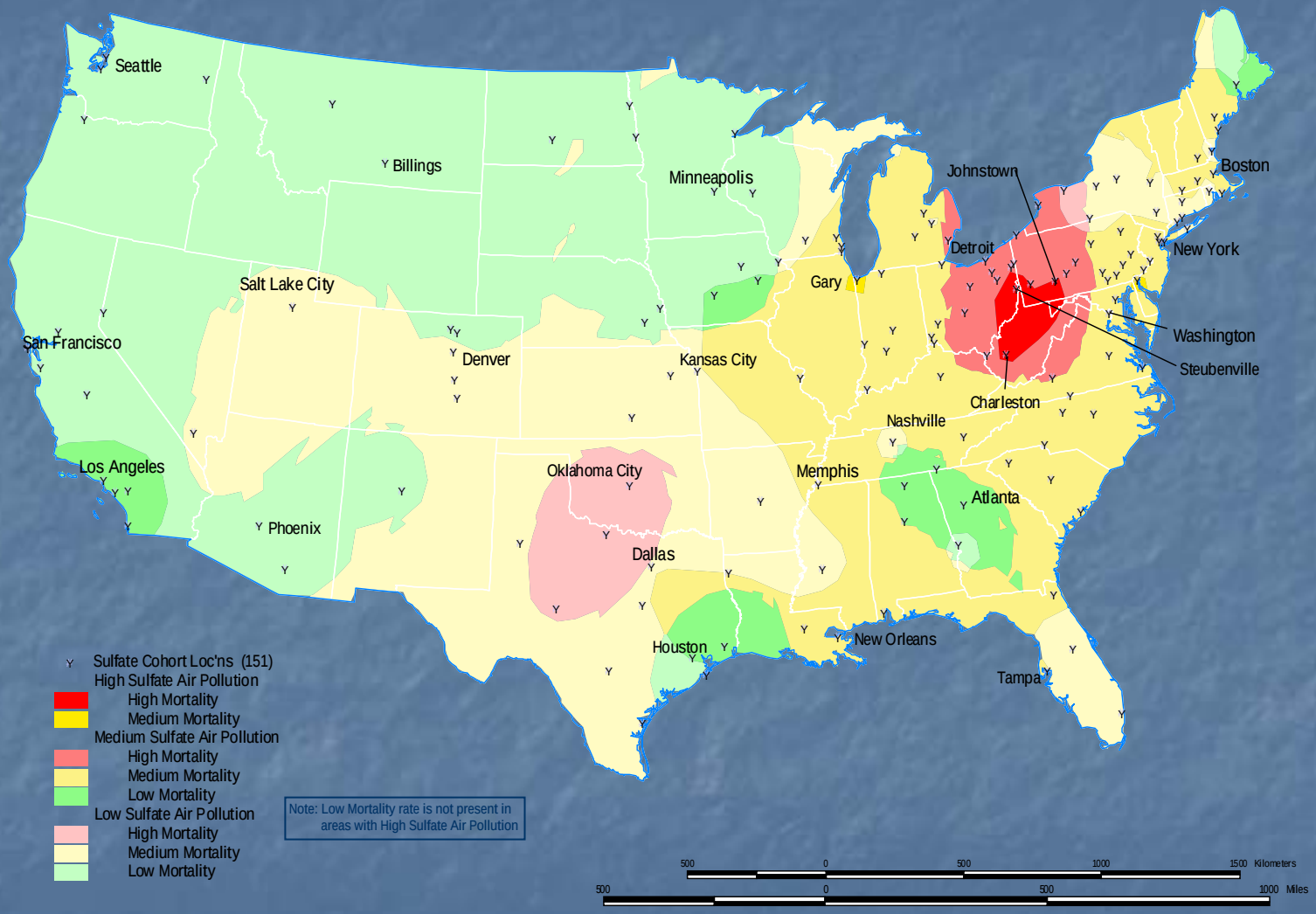


The American Cancer Society Study: Fine Particles

Mortality from:	Relative Risk (95% CI) for a 10$\mu g/m^3$ increase
All causes	1.06 (1.02-1.11)
Cardiopulmonary	1.09 (1.03-1.10
Lung cancer	1.14 (1.04-1.23)
Other causes	1.01 (0.95-1.06)

Pope et al. JAMA 2002;287:1132-41

Sulfate (SO_4) Air Pollution Levels
and
Mortality Rates (All Cause)



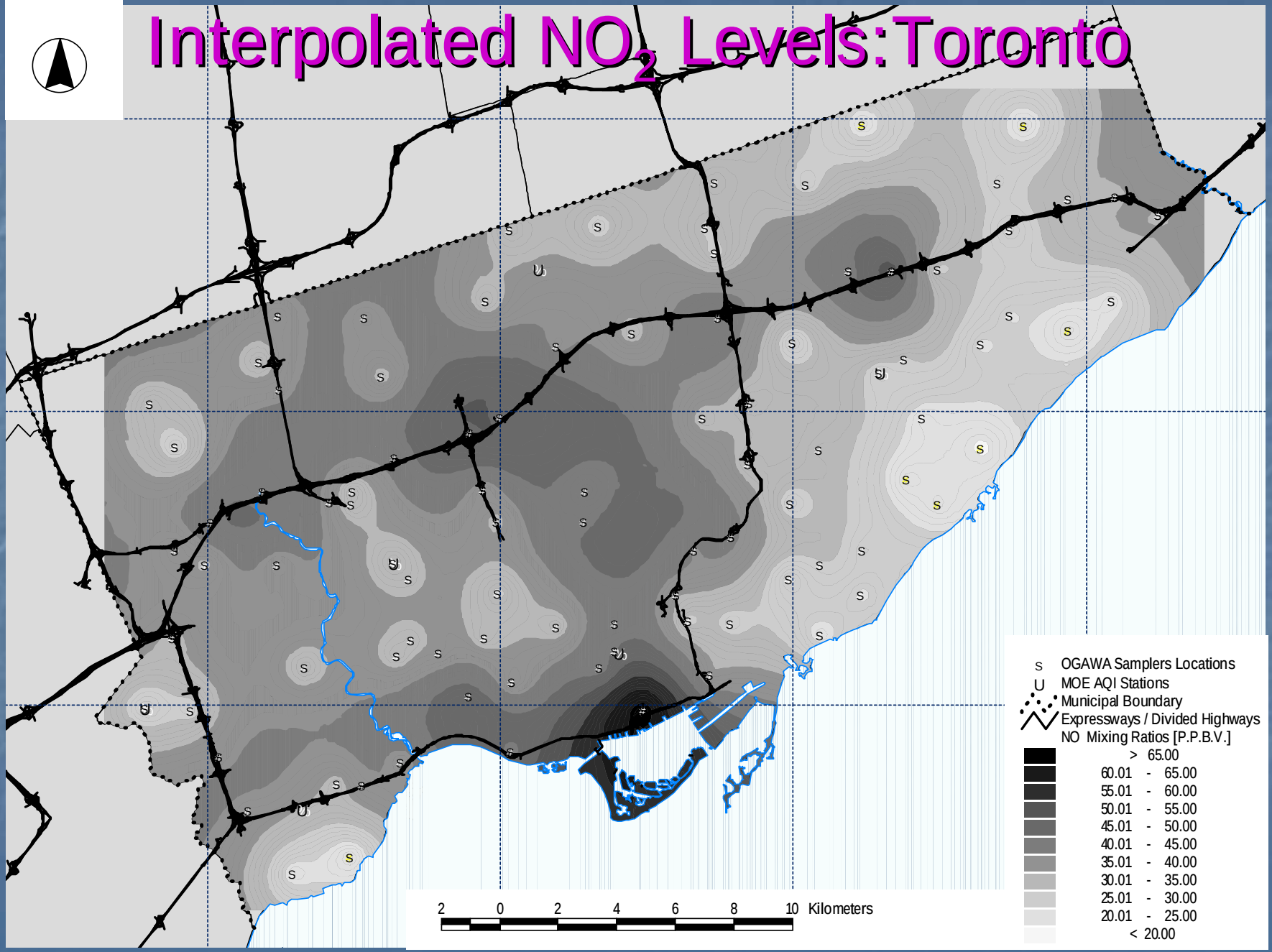
The Adventist Health Study of Smog: Fine Particles

	Relative Risk (95% CI) for a 24.8 $\mu g/m^3$ increase	
Mortality from:	Men	Women
All causes	1.11 (0.98-1.26)	0.94 (0.86-1.03)
Cardiopulmonary	1.10 (0.94-1.30)	0.92 (0.80-1.05)
Lung cancer	3.36 (1.57-7.19)	1.33 (0.60-2.96)

Abbey et al. Am J Resp Crit Care Med 1999;159:373-82

The Netherlands Cohort Study on Diet and Health

Interpolated NO_2 Levels: Toronto



The Netherlands Cohort Study on Diet and Health: Black Smoke & NO_2

	Relative Risk (95% CI) for an increase	
Mortality from:	B.S. (9.3 $\mu g/m^3$)	NO_2 (30.4 $\mu g/m^3$)
All causes	1.31 (0.95-1.80)	1.25 (0.83-1.89)
Cardiopulmonary	1.71 (1.10-2.67)	1.81 (0.98-3.34)
Non-Cardiopulmonary	1.09 (0.71-1.69)	1.08 (0.63-1.85)

Hoek et al., Lancet 2002;360:1203-9

Comparison of Relative Risks for Fine Particles (10 μg/m³)

Mortality from:	6-Cities	ACS	Adventist (Men/ Women)	Nether lands
All causes	1.13	1.06	1.05 0.98	1.34
Cardiopulmonary	1.18	1.09	1.04 0.97	1.78
Lung cancer	1.20	1.14	1.63 1.12	NA
Other causes	1.01	1.01	N/A	1.10

Other Evidence: Cardiovascular diseases

Short-term increases in fine particles related to:

- Heart attacks
- Decreased heart rate variability
- Defibrillator interventions
- Arterial vasoconstriction in healthy adults

Toronto CAP-Ozone Chamber Study

- Double-blind, cross-over study to controlled 24-hr exposures to concentrated Toronto particles
- Particles (150$\mu g/m^3$) with O_3 (120 ppb)
- Two hour inhalation led to increased brachial artery vasoconstriction.
- Proposed mechanism: endothelins

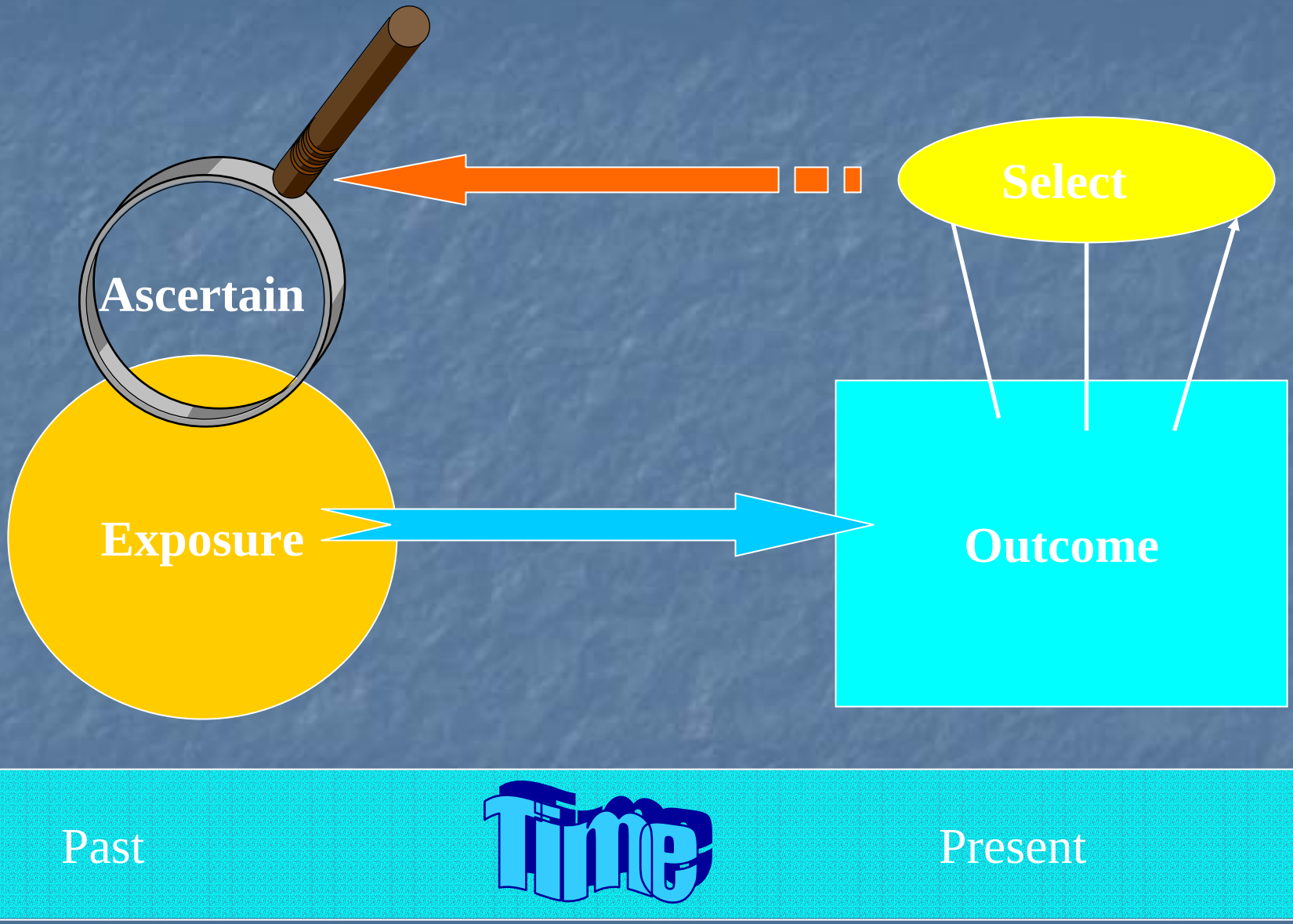
Brook, Circulation 2002;105:1534-36

Interaction with Social Class

- 3 cohort studies showed that the air pollution effects increased with lower levels of attained education
- Possible explanations:
  - persons in disadvantaged areas are more susceptible to the effects of air pollution
  - local levels of air pollution in disadvantaged areas are higher than the city-wide averages used in the analyses, so the observed effect is due simply to measurement error

Case-Control Studies

Case-control Studies



Lung Cancer

Area	Metric	OR (95%CI)	Ref.
Los Angeles	High levels TSP, benzo[a]pyrene	1.3 (NS)	Pike 1979
Buffalo	High levels TSP	1.7 (1.0-2.9)	Vena 1983
Krakow	High levels particles	1.5 (1.1-2.0)	Jedrychow-ski 1990
Trieste	Estimated levels of deposition of particles: >0.298 g-m^2/day	1.4 (1.1-1.8)	Barbone 1995; Biggeri 1996

Lung Cancer

Area	Metric	OR (95%CI)	Ref.
Northeastern China	Perceived smokiness in the outdoor environment	Somewhat: 1.5 (1.2-2.0) Smoky: 2.3 (1.7-2.9)	Xu 1989, 1996
Athens	High concentrations of soot	1.1	Katsouyanni 1991
Stockholm	NO_2 averaged over a 30-year period (traffic density/dispersion models): >29$\mu g/m^3$	1.4 (1.1-2.0)	Nyberg 2000

Childhood Cancer

Area	Cancer sites	Metric	OR (95%CI)
Denmark	Leukemias, CNS, lymphomas	Benzene and NO_2 before pregnancy of during childhood	No associations
	Lymphomas	Benzene and NO_2 during pregnancy: doubling of exposure	Benz: 1.3 (1.0-1.6) NO_2: 1.5 (1.0-2.3)
	Hodgkin's disease	Doubling of exposure	Benz: 1.8 (1.2-2.8) NO_2: 2.5 (1.2-5.3)

Raaschou-Nielsen 2001 AJE 153:433-443

Childhood Cancer

Area	Cancer sites	Metric	OR (95%CI)
Sweden	All cancer	NO_2 per $\mu g/m^3$	1.02 (1.00-1.04)
	All cancer	$\leq$49 $\mu g/m^3$ 50-79 $\geq$80	1 1.9 (0.8-4.5) 3.8 (1.2-12.1)
	Leukemias	NO_2 per $\mu g/m^3$	1.02 (0.98-1.06
	CNS	NO_2 per $\mu g/m^3$	1.04 (1.00-1.08

Feychting, 1998 Scand J Work Environ Health 24:8-11

Childhood Cancer

Area	Cancer sites	Metric	OR (95%CI)
Denver	Leukemias	Highest to lowest traffic density category	4.7 (1.6-13.5)
	Lymphomas		0.7 (0.2-3.0)
	Brain		1.7 (0.8-3.9)
	Soft tissue		1.4 (0.5-4.4)
	All cancers combined		1.7 (1.0-2.8)

Savitz 1989 Scand J Work Environ Health 15:360-363

Childhood Cancer

Area	Cancer sites	Metric	OR (95%CI)	Ref.
San Diego	Leukemias	Traffic density	No assocns.	Reynolds 2001
Los Angeles County	Leukemias	Traffic density of the longest residence of the subject	5th versus 1st quintile: 1.9 (0.9-3.7)	Langholz 2002

Occupational Evidence

- Exposure to combustion products increases DNA mutations (e.g., from DNA adducts of polycyclic aromatic hydrocarbons)
- Numerous studies show associations with different sites of cancer
  - Diesel fumes/particles
  - Benzene, vinyl chloride, PAHs (BaP), formaldehyde, ethene, butadiene, alkenes, acetaldehyde (see Tormqvist 1994)

Cancer and Air Pollution in Montreal

- Objectives:
  - 1) To determine whether exposure to traffic-related air pollution is associated with cancer incidence
  - 2) To determine whether relative risks for air pollution are higher in disadvantaged areas

- Makes use of 4 case-control studies carried out in Montreal:
  - Multi-site study in men
  - Lung cancer in men and women
  - Childhood leukemia
  - Breast cancer

Existing Data

- Residential histories
- Personal information on risk factors
  - E.g., breast cancer: reproductive history, alcohol consumption
  - Occupational exposures
  - Other environmental exposures
    - E.g., environmental tobacco smoke

New Data

- “Natural neighbourhoods” (Nancy Ross, McGill)
- Land-use model to find optimal sampling sites (Jerrett, McMaster)
- Exposure monitoring campaign for traffic-related air pollution (NO_2, VOCs, PAHs, elemental carbon) (Jeff Brook, Environment Canada; Nicolas Gilbert, Health Canada; Jim Nicell, McGill)

- Traffic density (Murtaza Heider, Urban Planning, McGill)
- Fixed-site monitoring data (City of Montreal)
- Spatial smoothing and historical reconstruction of exposure
- Random effects logistic models (Renjun Ma, University of New Brunswick; Rick Burnett, Health Canada; Ed Hughes, Ottawa)

Intake and Follow-up of Cohorts