Climate Change and Health:

Methods of Analyzing Climate-Disease Associations

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Reminder: Some definitions

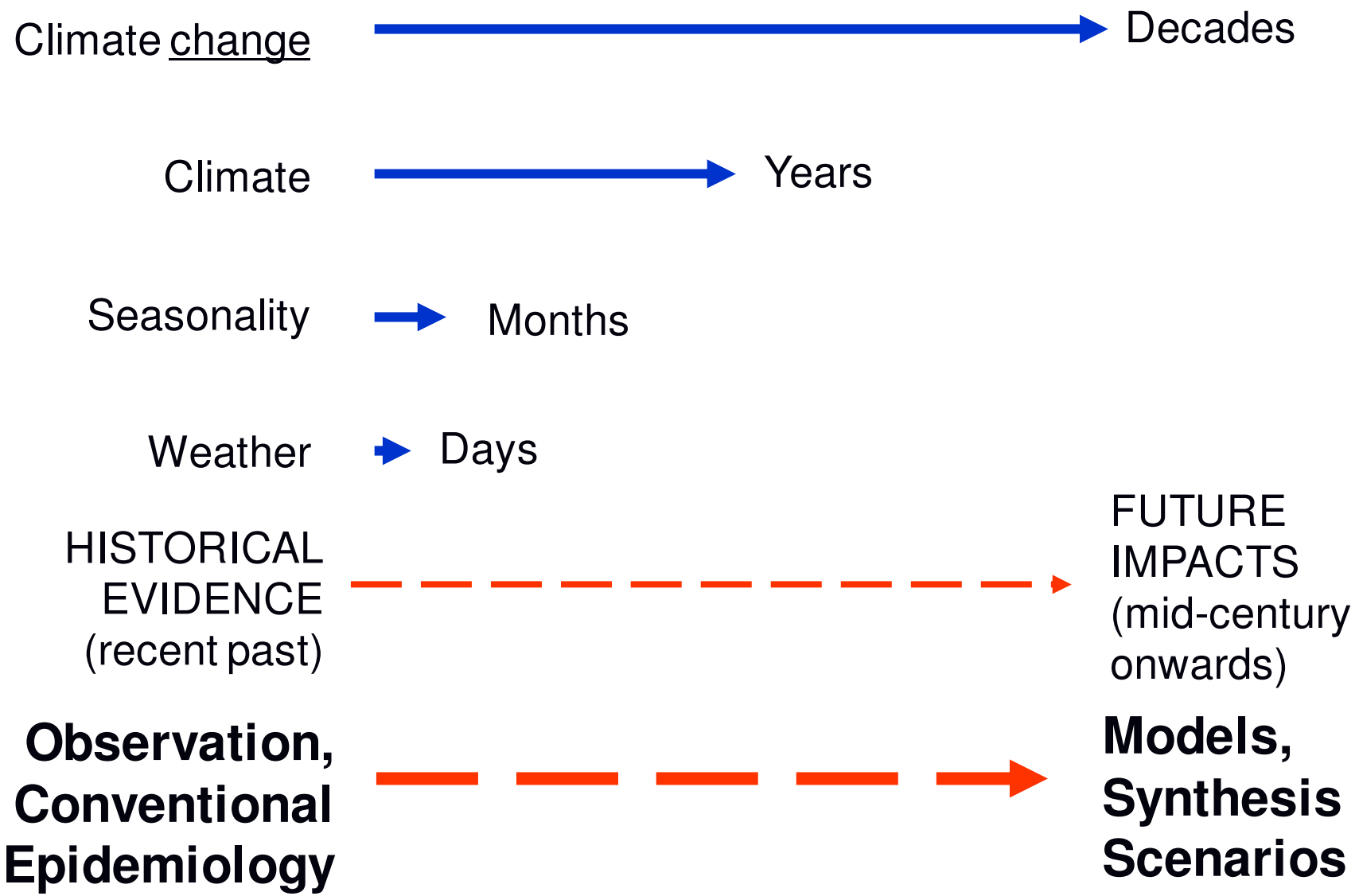
***Weather**:* the day-to-day atmospheric conditions in a specific place at a specific time

***Climate**:* the average state of the atmosphere and the underlying land or water in a specific region over a specific time scale

***Climate Variation**:* fluctuations in a weather variable over periods of weeks/months or between seasons that are above and below average

***Climate change**:* trend in the average toward more or less of a weather variable detectable over extended periods (typically decades or longer)

Reminder: Some definitions



Types of Climate-Health Analysis

OBSERVATIONAL

(1) Episodes or event analysis: heat wave, flood, drought…

(2) Time-series analysis: mortality vs. temperature, precipitation

(3) Seasonality: diarrhea, aero-allergens

(4) Changes in geographical distribution: temperature/precipitation vs VBDs

MODEL-BASED

(1) Health burdens: risk assessments

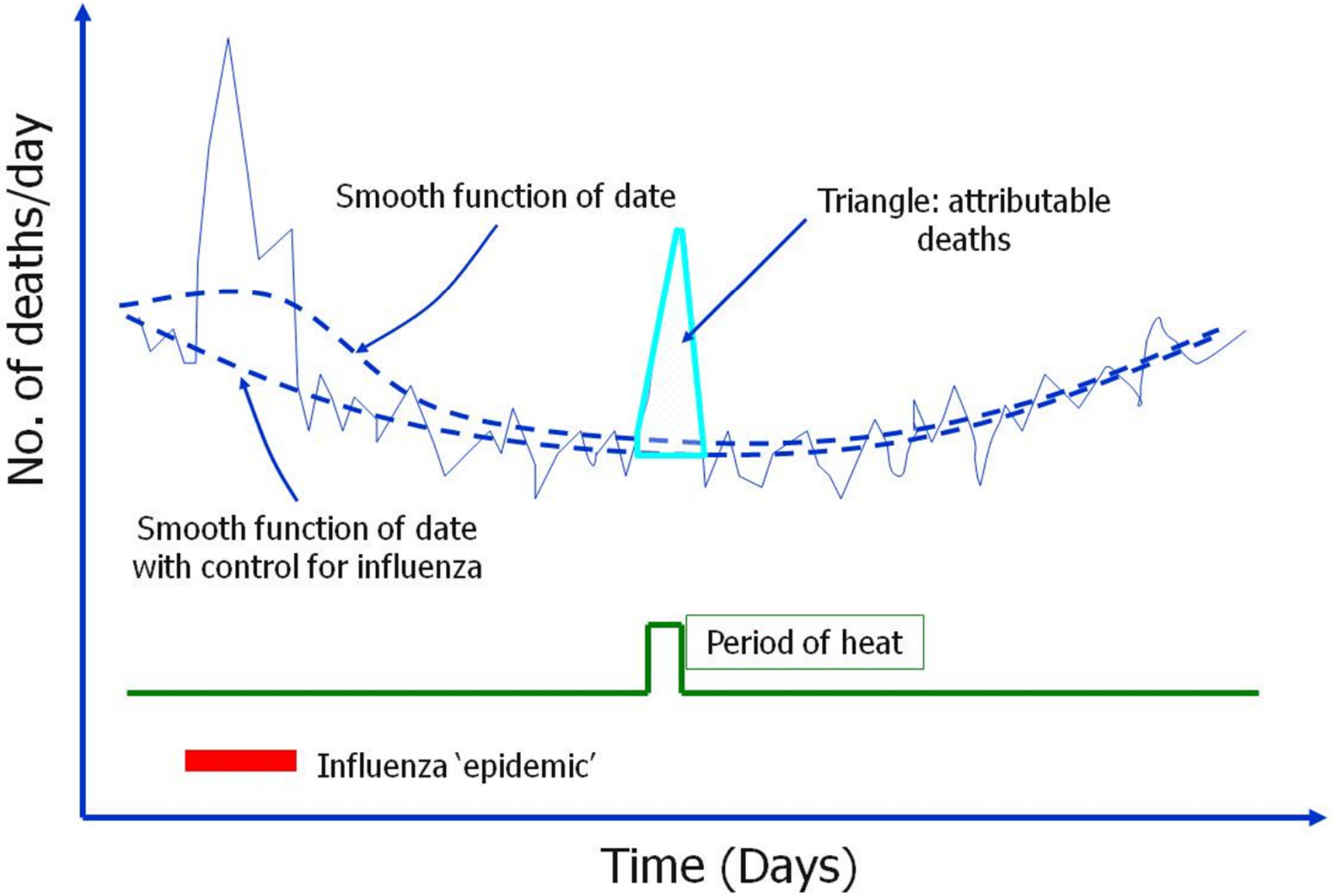
(2) Decisions analysis of health impact of policy options

Daily changes: two approaches

- **Episode analysis**
  - transparent
  - risk defined by comparison to local baseline

- **Regression analysis** of all days of year (time-series)
  - uses full data set
  - requires fuller data and analysis of confounders
  - can be combined with episode analysis

Principles of episode analysis



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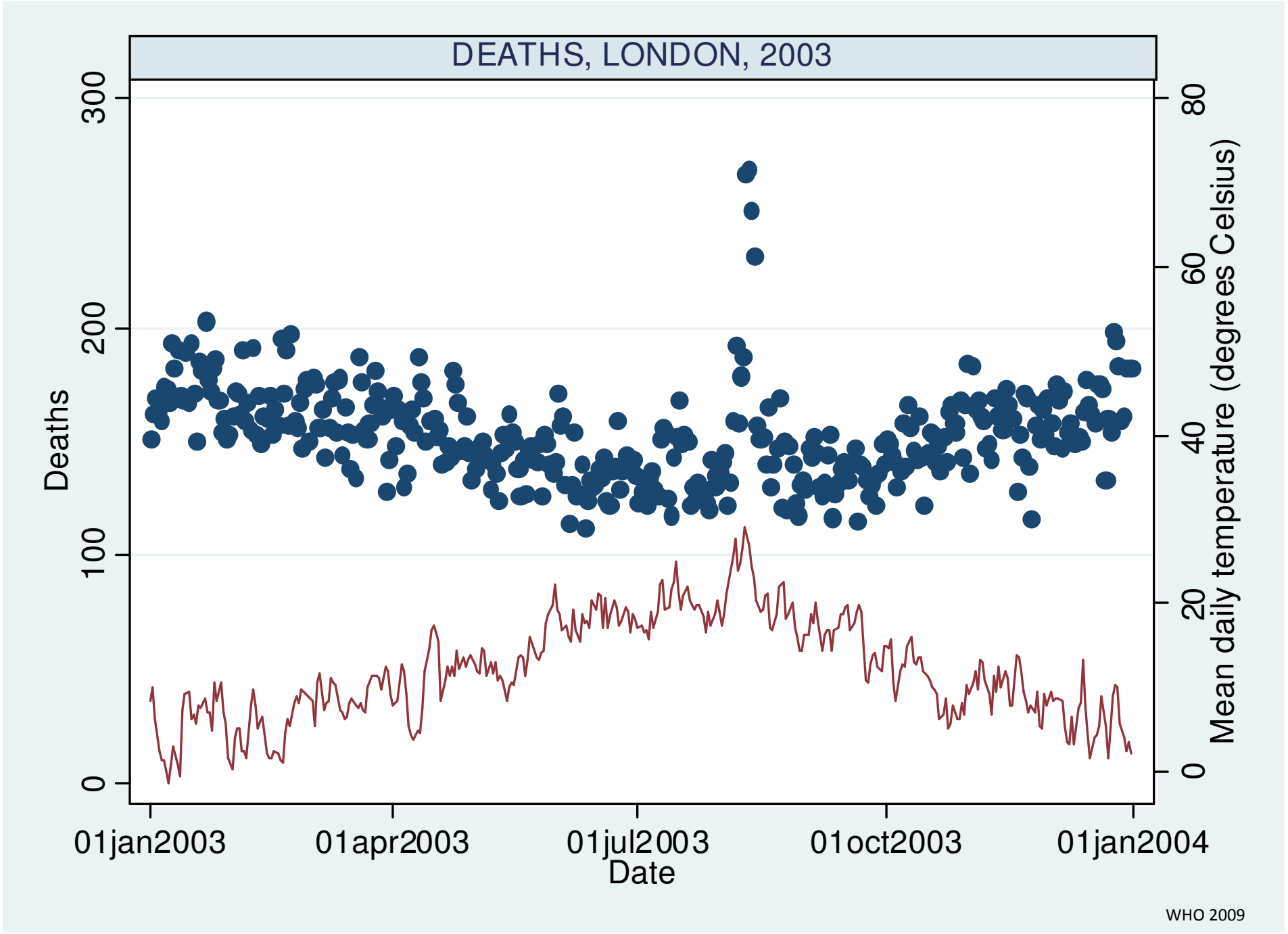
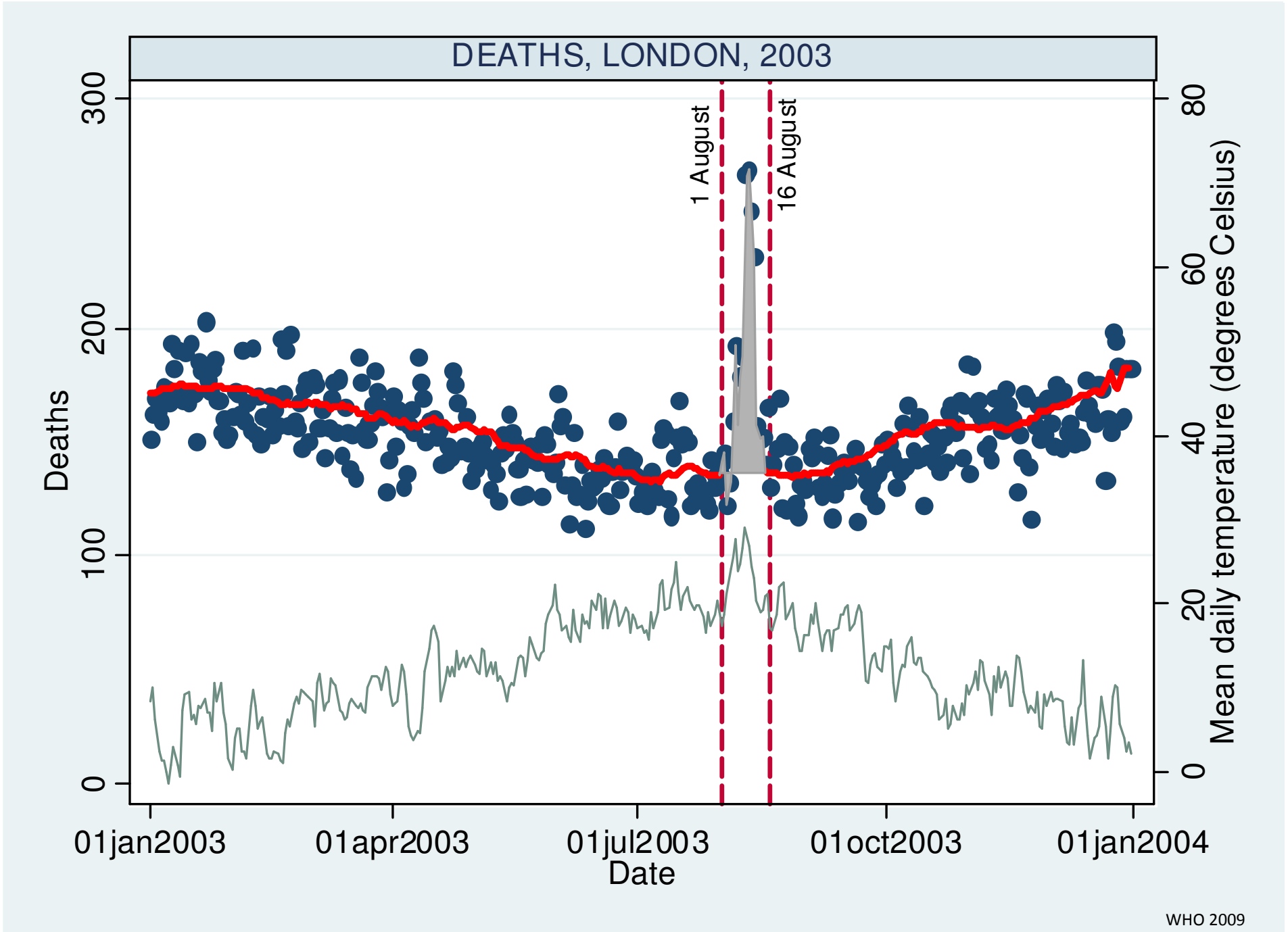
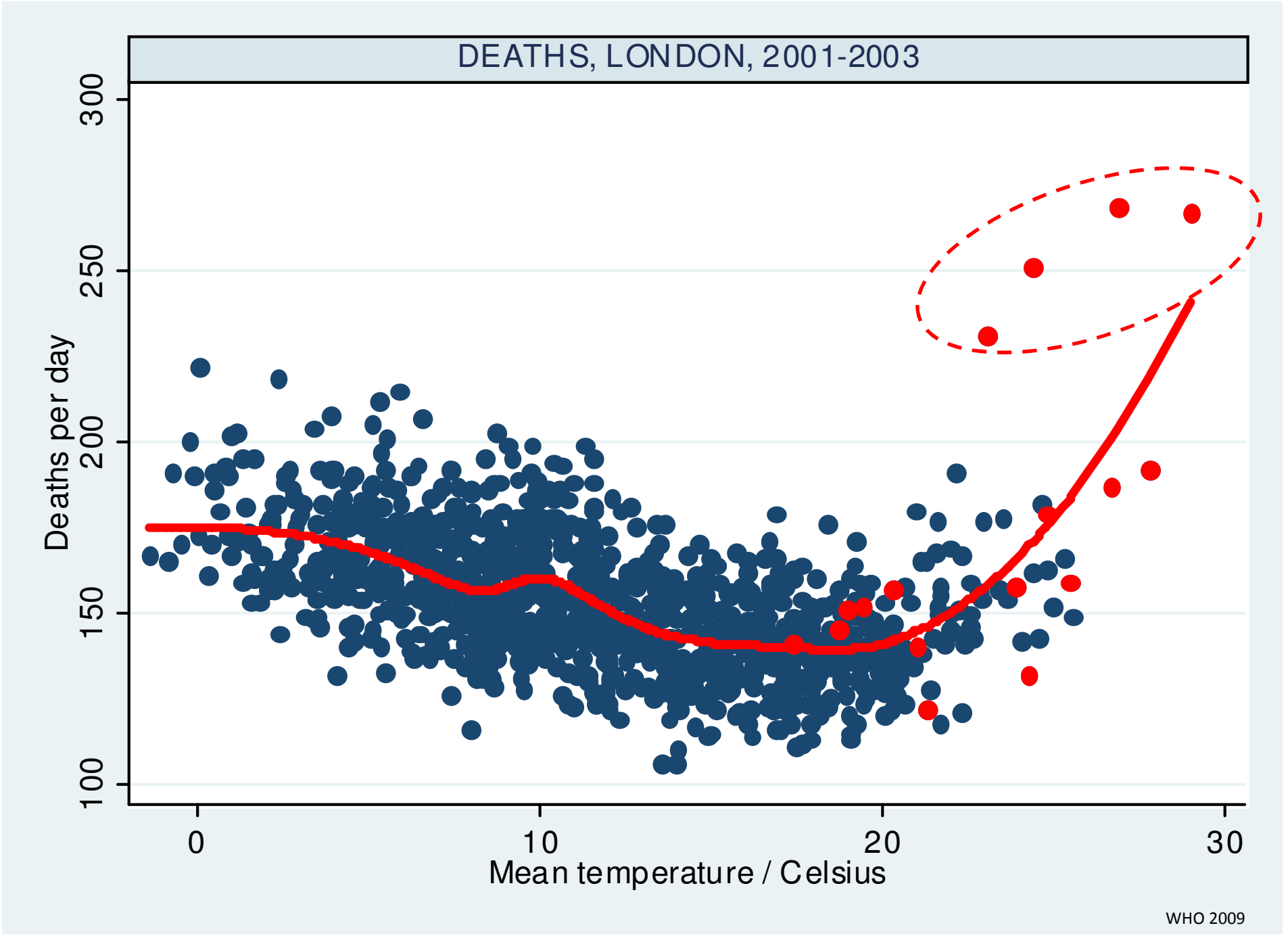

DEATHS, LONDON, 2003
Deaths
0
100
200
300
Mean daily temperature (degrees Celsius)
0
20
40
60
80
01jan2003
01apr2003
01jul2003
01oct2003
01jan2004
Date
WHO 2009


DEATHS, LONDON, 2003
1 August
16 August
Deaths
0
100
200
300
Mean daily temperature (degrees Celsius)
0
20
40
60
80
01jan2003
01apr2003
01jul2003
01oct2003
01jan2004
Date
WHO 2009


DEATHS, LONDON, 2001-2003
Deaths per day
300
250
200
150
100
0
10
20
30
Mean temperature / Celsius
WHO 2009

Interpretation

- Common sense, transparent
- Relevant to Public Health warning systems

However

- How to define episode?
  - relative or absolute threshold
  - duration
  - composite variables
- Uses only selected part of data
- More sophisticated analysis requires same methods as for regression of all days of year

Time-series regression

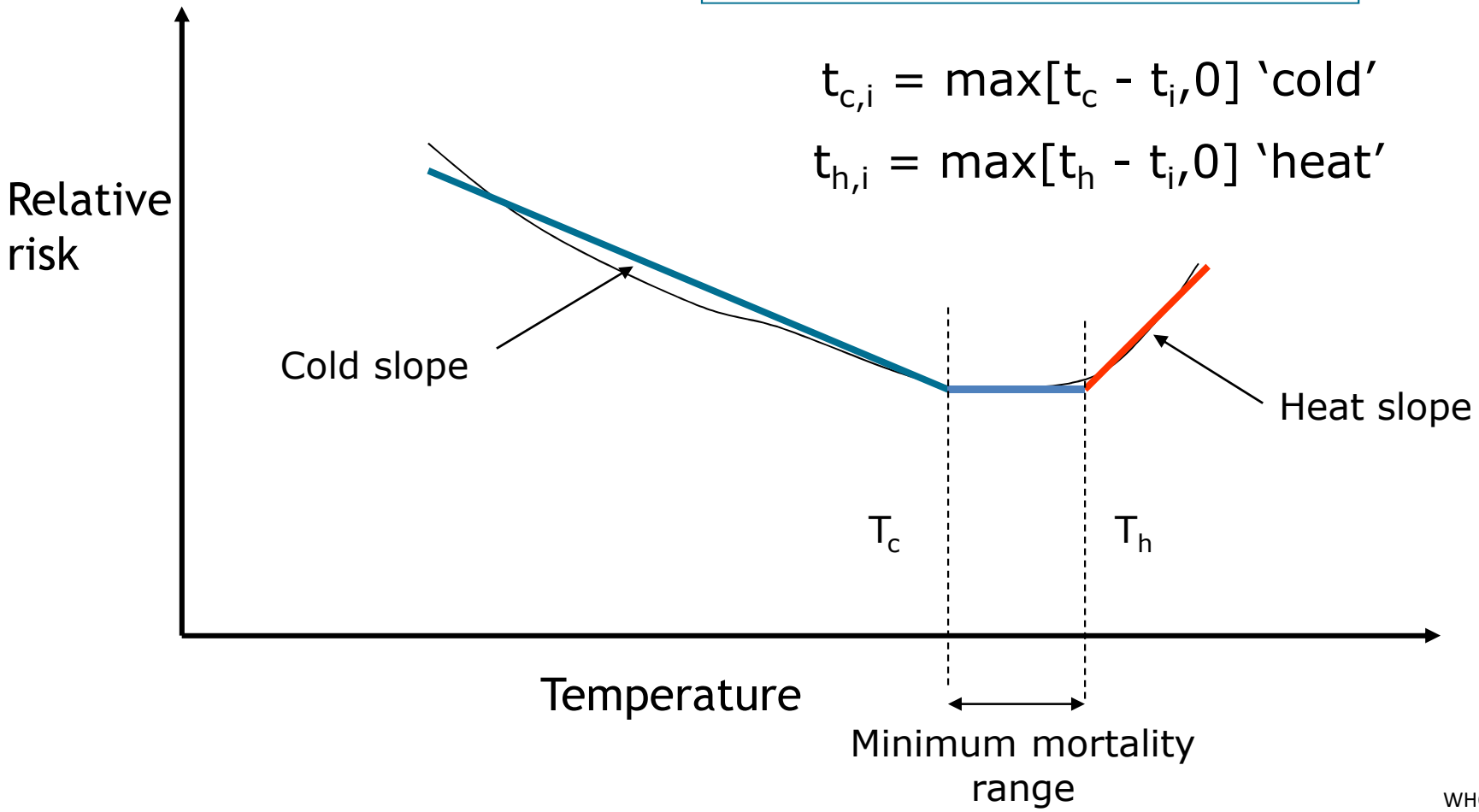
- Short-term temporal associations
- Daily/weekly
- Suitable for episodes or effects of local fluctuations in meteorological parameters
- U- or V-shape of temperature-response function
- Different lags

Parameterization: hockey-stick models

$$f(t_i, \beta) = \beta_c t_{c,i} + \beta_h t_{h,i}$$

$t_{c,i} = \max[t_c - t_i, 0]$ 'cold'

$t_{h,i} = \max[t_h - t_i, 0]$ 'heat'



The model

$$\text{(log) rate} = \beta_0 + \beta_1(\text{high temp.}) + \beta_2(\text{low temp.}) + \beta_3(\text{pollution}) + \beta_4(\text{influenza}) + \beta_5(\text{day, PH}) + \beta_6(\text{season}) + \beta_7(\text{trend})$$

β_1=heat slope

β_2=cold slope

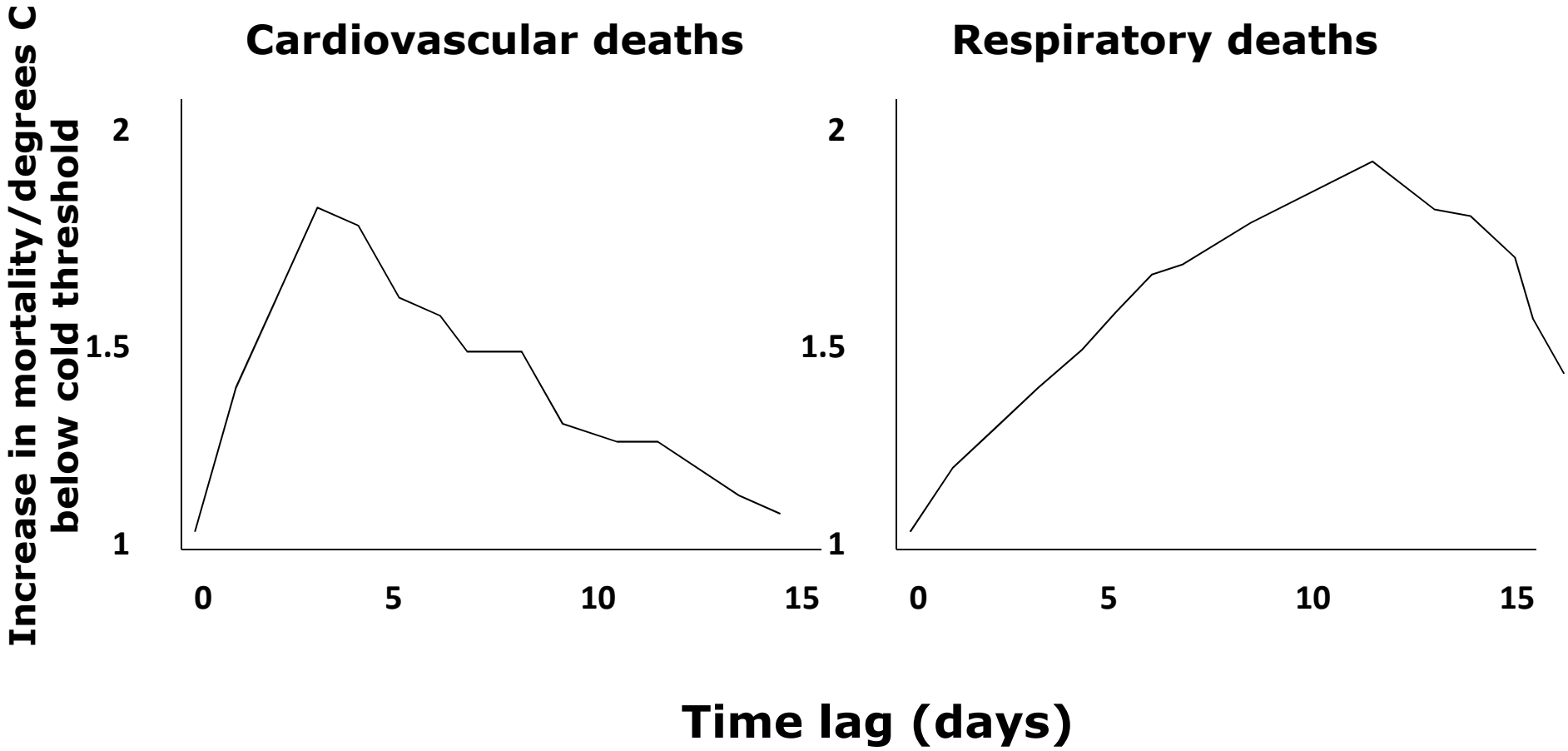
measured confounders

unmeasured confounders

Lags

- Heat impacts short: 0-2 days
  Cold impacts long: 0-21 days
- Vary by cause-of-death
  - CVD: prompt
  - respiratory: slow
- Should include terms for all relevant lags

Lags for cold-related mortality, London



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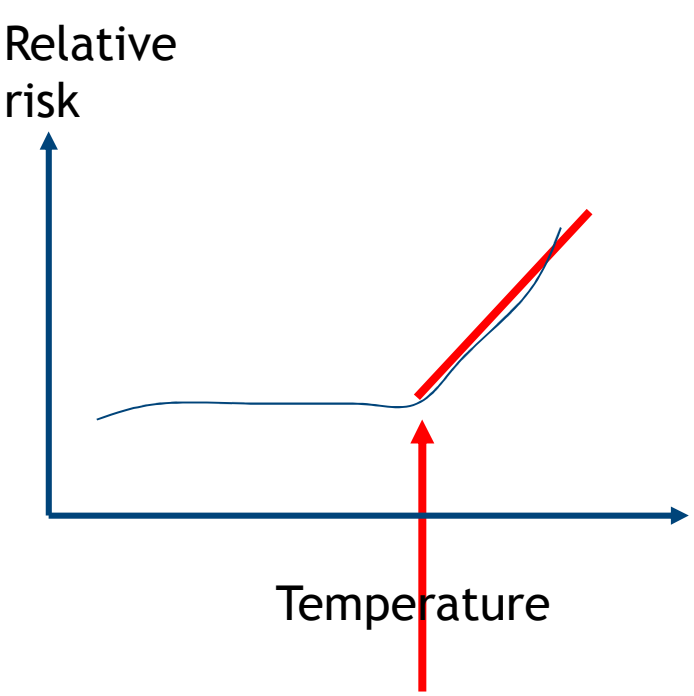
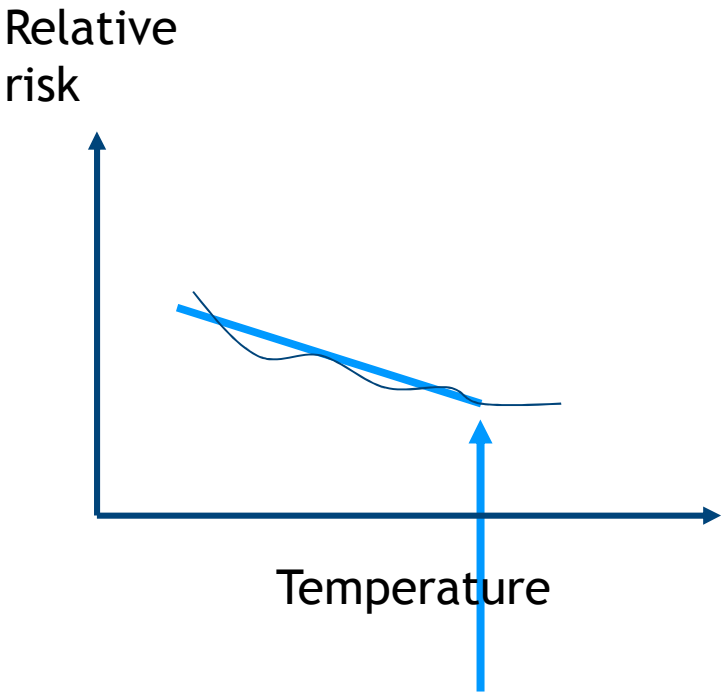
LAG: 0-1 DAYS (HEAT)



Threshold for heat effect

LAG: 2-13 DAYS (COLD)



Threshold for cold effect

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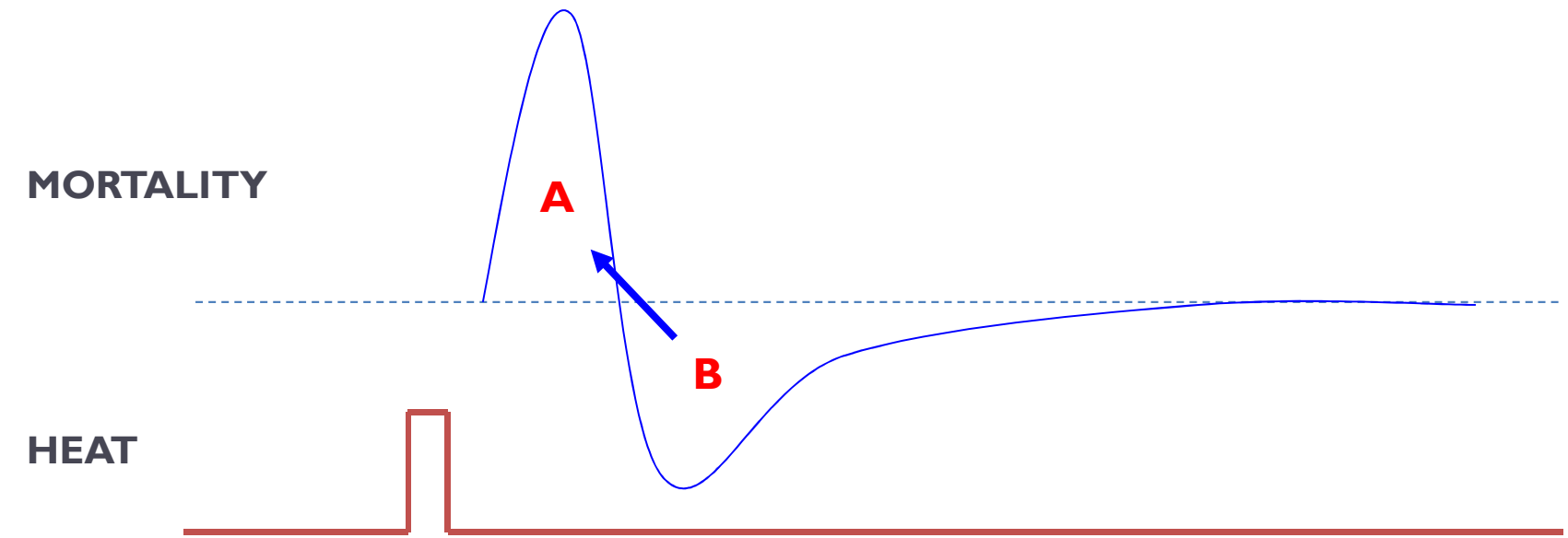
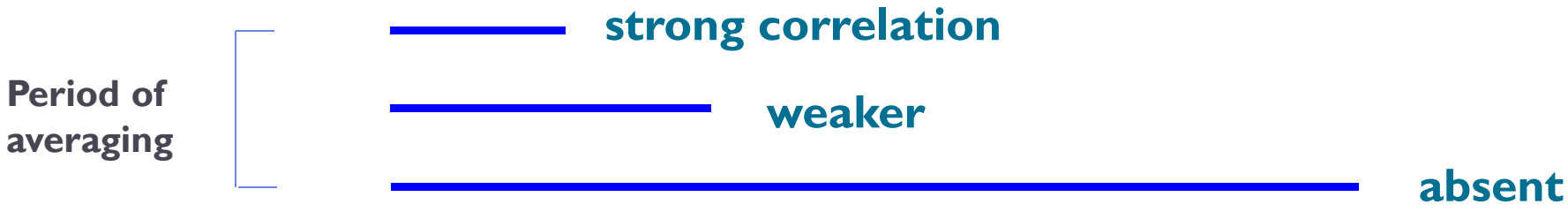
Mortality displacement: schema





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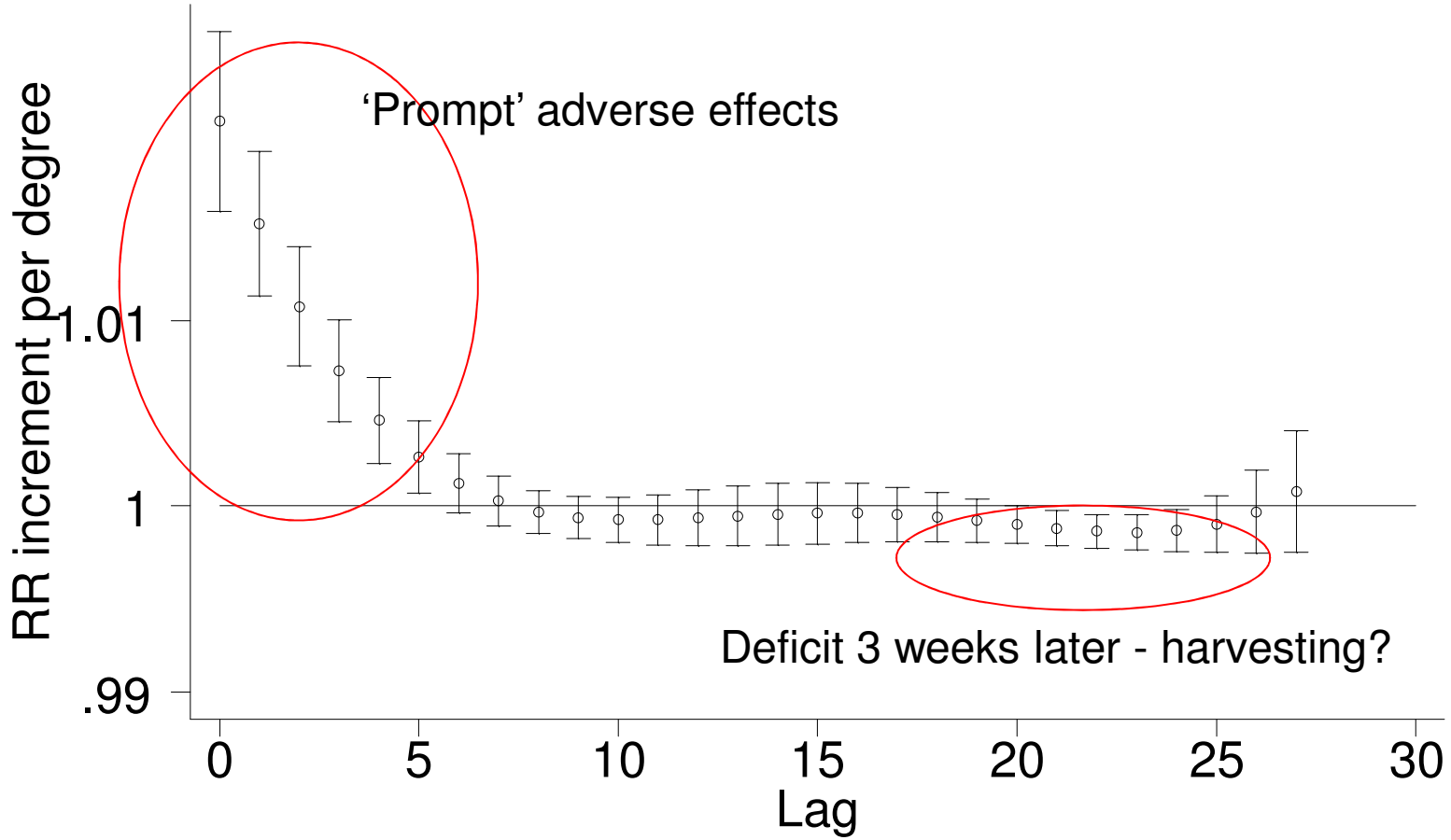
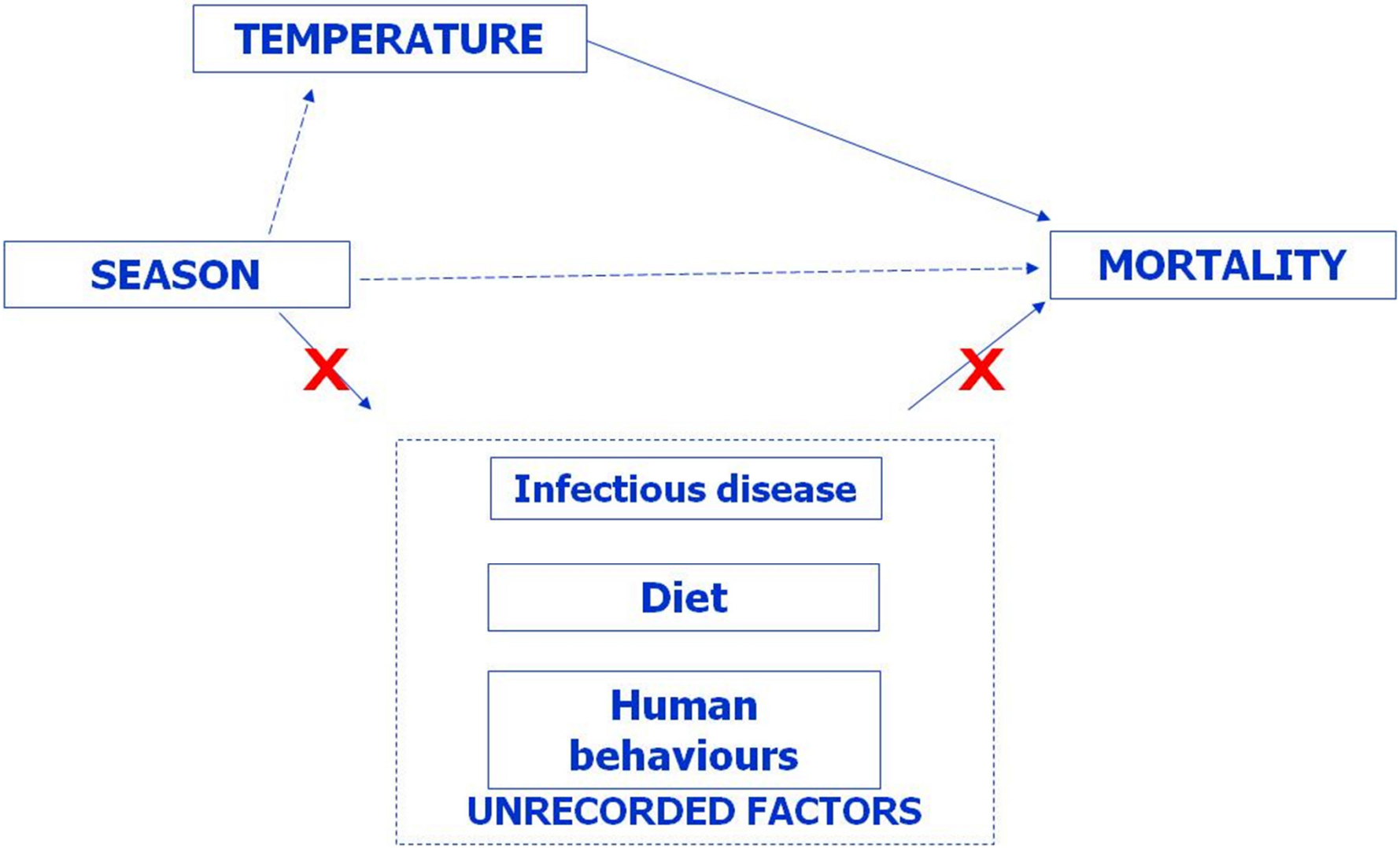
Constrained distributed lag model: “harvesting” interpretation



Controlling for season



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Methods of seasonal control

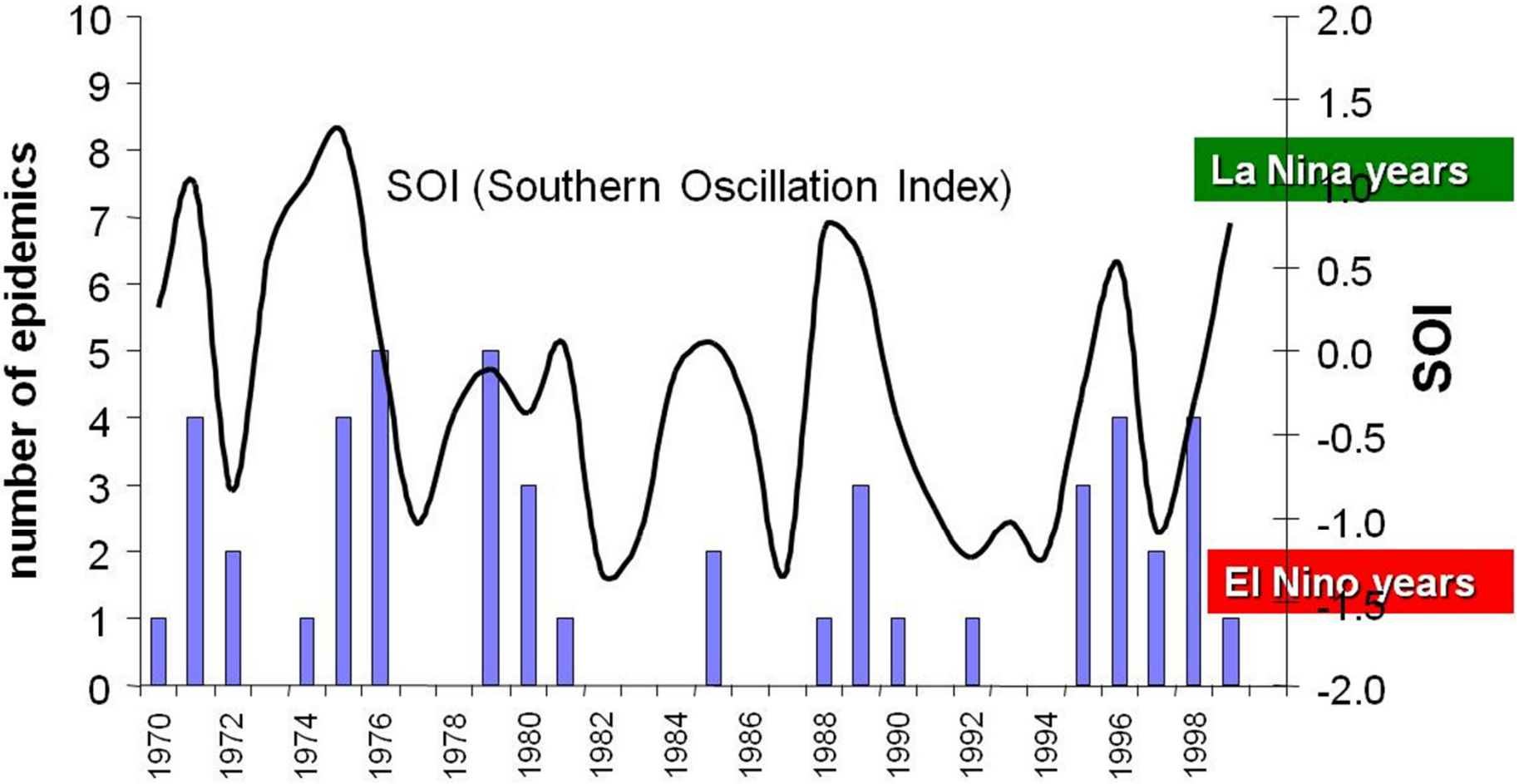
- **Moving averages**
- **Fourier series** (trigonometric terms):

  $Fn(x) = a0 + (a1\cos(x) + b1\sin(x)) + \ldots + (a_n\cos(nx) + b_n\sin(nx))$

  where a0, b0, a1, b1,… are coefficients of Fn(x)
- **Smoothing splines**
- **Stratification by date**
- Other…

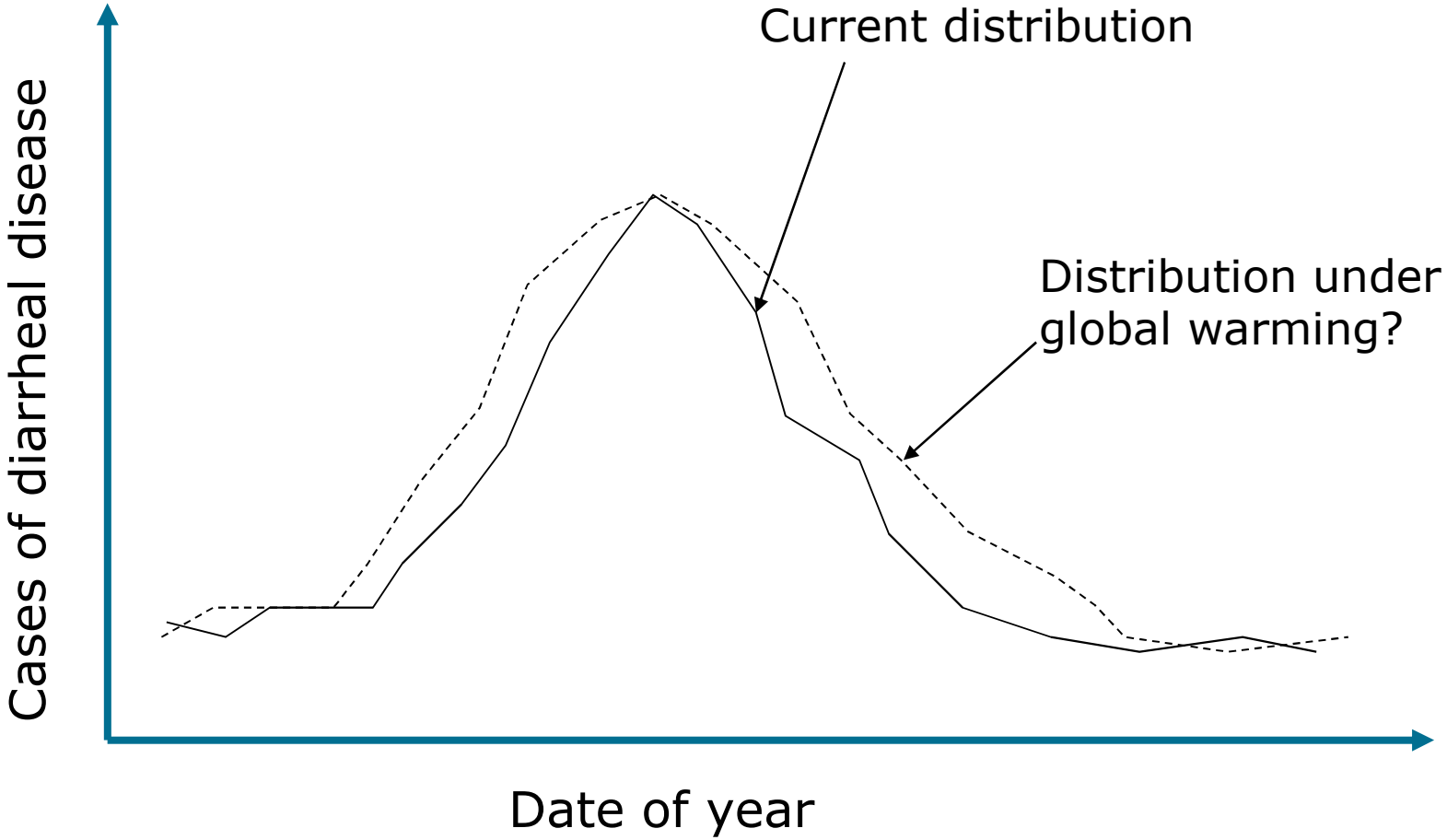
Inter-annual variation

Example of Dengue Epidemics in the South Pacific, 1970-1998



Hales and Woodward, 1999

Seasonality



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Summary of time-series

- Provides evidence on **short-term associations** of weather and health
- **Robust** design
- **Repeated** finding of direct heat + cold effects
- Some uncertainties over **public health** significance
- Uncertainties in **extrapolation** to future
- **Remember**: **Not** a historical analogue of longer-term climate change

Changes in geographical distribution of disease risk

BIOLOGICAL MODELS

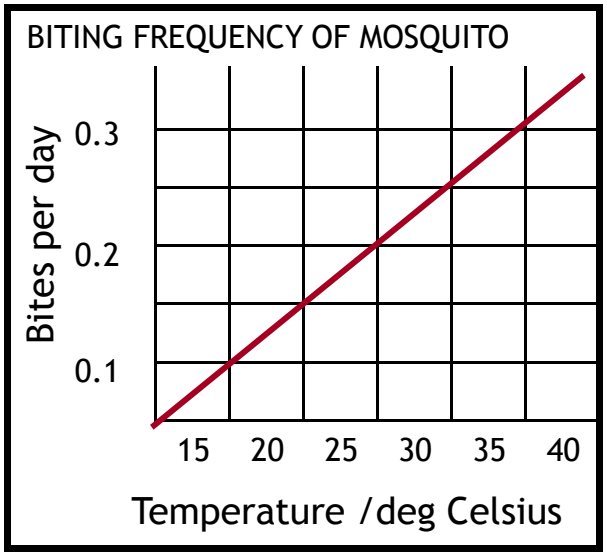
- Use of (laboratory-derived) biological evidence

STATISTICAL MODELS

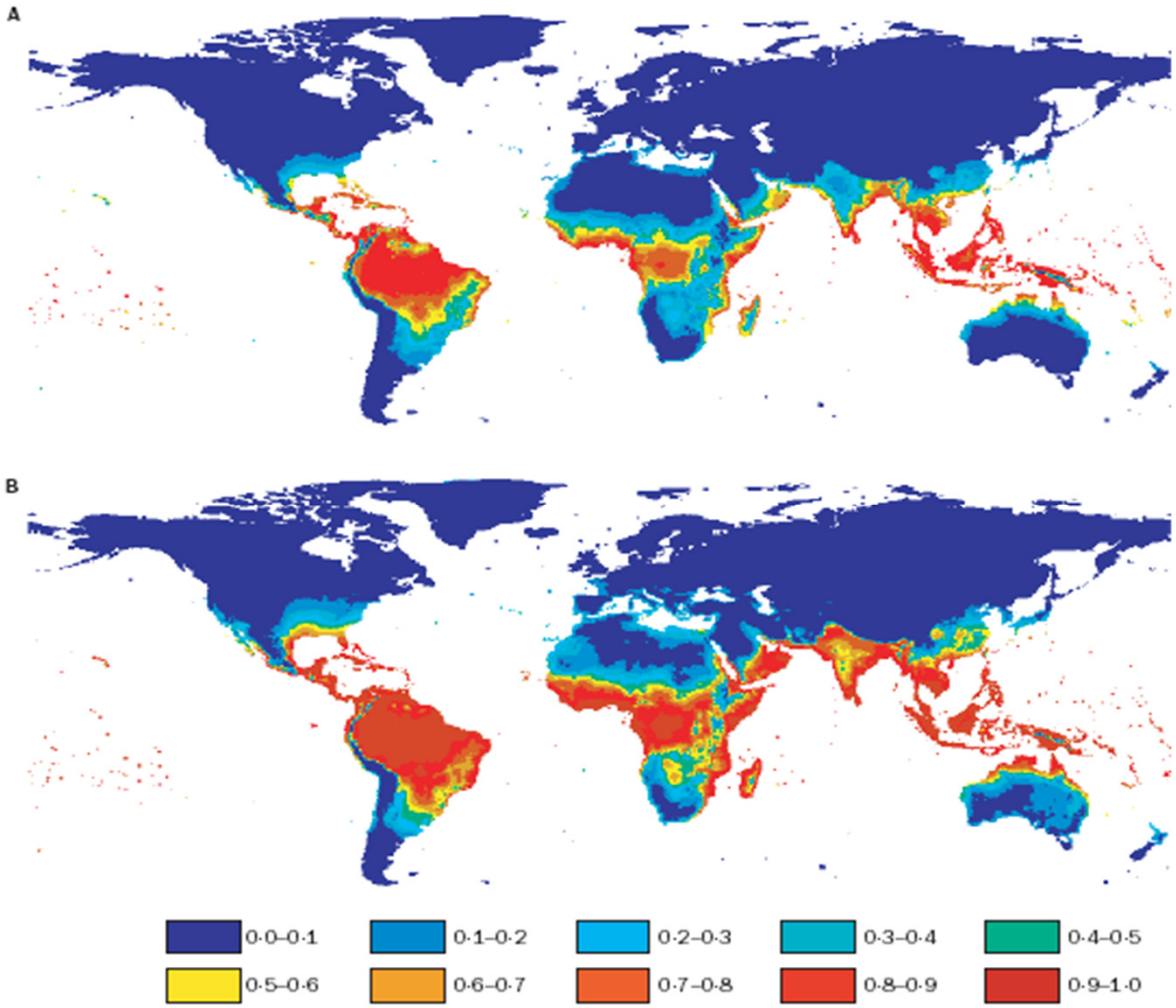
- Analyses of disease prevalence or vector abundance in relation to geographical factors

SIMULATION MODELS

- Forecast based on dynamical extrapolation involving multiple factors that include biological, social and economic.


BITING FREQUENCY OF MOSQUITO
Bites per day
0.3
0.2
0.1
15
20
25
30
35
40
Temperature /deg Celsius

Estimated population at risk of dengue fever (A) 1990, (B) 2085



Source. Hales S et al. Lancet (online) 6 August 2002.
http://image.thelancet.com/extras/01art11175web.pdf

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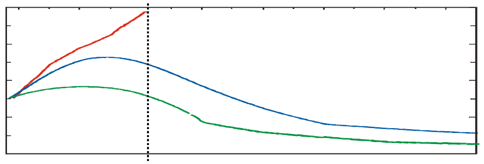
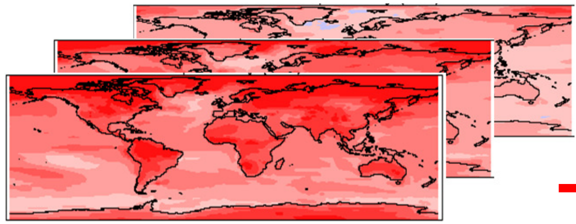
Future burdens: risk assessment

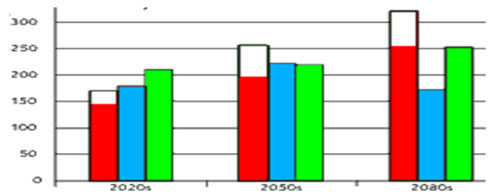
GHG emissions:
scenarios defined by IPCC



GCM model:
Generates series of maps of predicted future distribution of climate variables



Health impact model: **Generates comparative estimates of the regional impact of each climate scenario on specific health outcomes**



Conversion to GBD 'currency'
to allow summation of the effects of different health impacts

Level	Age group (years) 0-4	5-14	15-29	30-44	45-59	60-69	70+
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3	1.7	1.7	1.7	1.7	1.7	1.7	1.7

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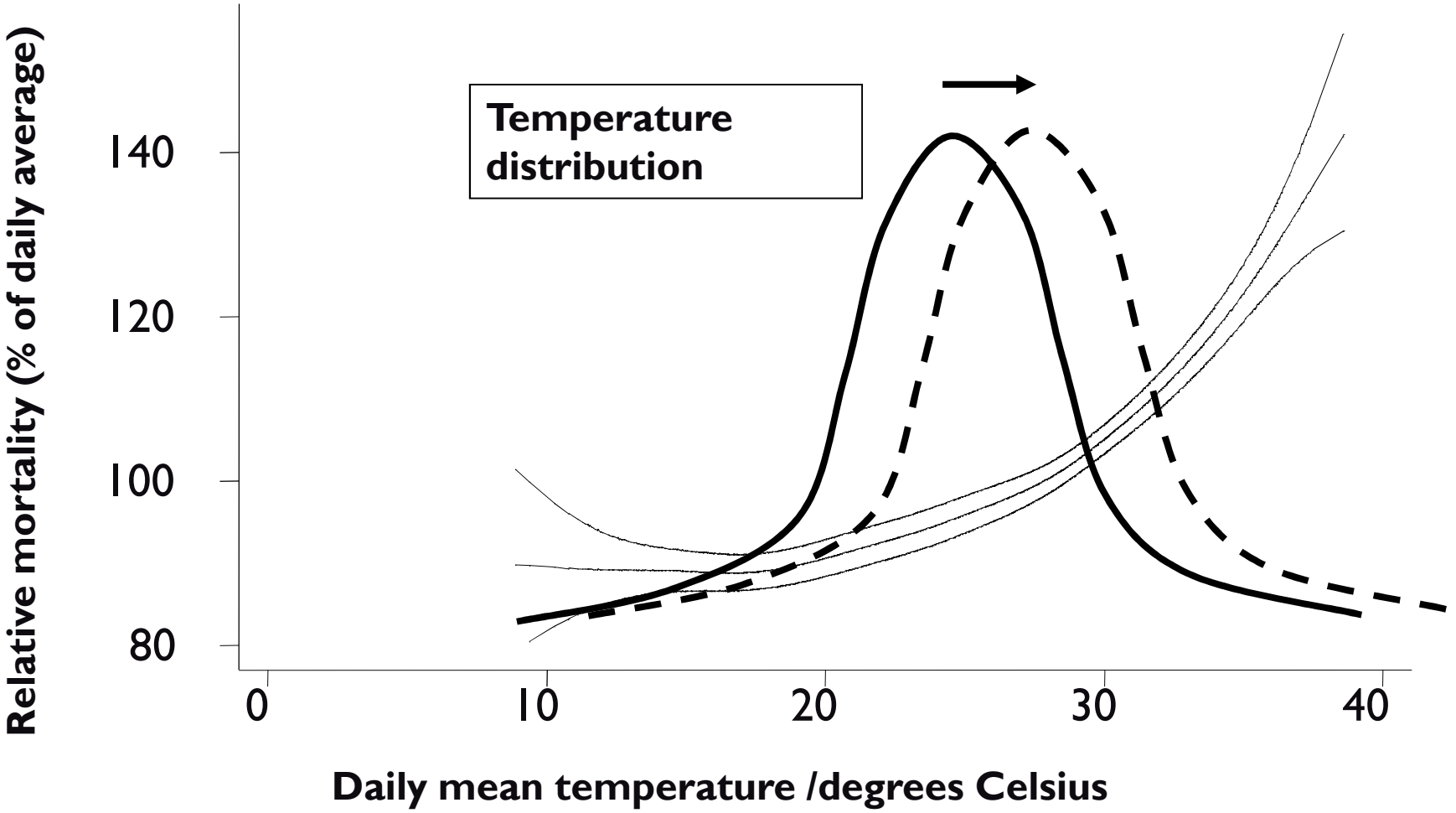
Heat-related mortality (Delhi)



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Uncertainties

- **EXTRAPOLATION**
  (going beyond the data)

- **VARIATION**
  (..in weather-health relationship -- largely unquantified)

- **ADAPTATION**
  (we learn to live with a warmer world)

- **MODIFICATION**
  (more things will change than just the climate)

Changing vulnerability

- **Changes in population**
  - Demographic structure (age)
  - Prevalence of weather-sensitive disease
- **Environmental modifiers**
- **Adaptive responses**
  - Physiological habituation (acclimatization)
  - Behavioral change
  - Structural adaptation
  - Public Health interventions

Conclusions

- Most methods of 'climate' attribution based on analysis of weather-health associations: episode analysis, time-series, seasonality, inter-annual variations
- Relevance to climate change limited by uncertainties over multiple effect-modifiers or changes in vulnerability of population & health
- Modelling intrinsic to assessment of likely future burdens and the effect of adaptation options, but entails many uncertainties

Discussion

Questions?

Thoughts?

Concerns?

Suggestions?

Acknowledgements

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- Some material was modified from the WHO “Training course for public health professionals on protecting our health from climate change (2009).”

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