Recent Evidence on the Relationship between Ozone and Mortality

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Health Impacts of Ozone

- Effects on lung function
- Respiratory symptoms
- Exacerbation of asthma
- Hospital admissions
- Emergency room visits
- **Mortality?**

Source: EPA. *Air Quality Criteria for Ozone and Related Photochemical Oxidants*. **1996**

Recent Studies on Ozone and Mortality

- Study designs
  - Meta-analysis, multi-city time-series, case-crossover
- Confounders
  - Weather, particulate matter
- Effects at low levels

Meta-Analysis Approach

- Systematically review the literature to find studies
- 144 effect estimates from 39 time-series studies
  - 38 in the U.S., 106 from outside the U.S.
- Combine the estimates using a Bayesian hierarchical model

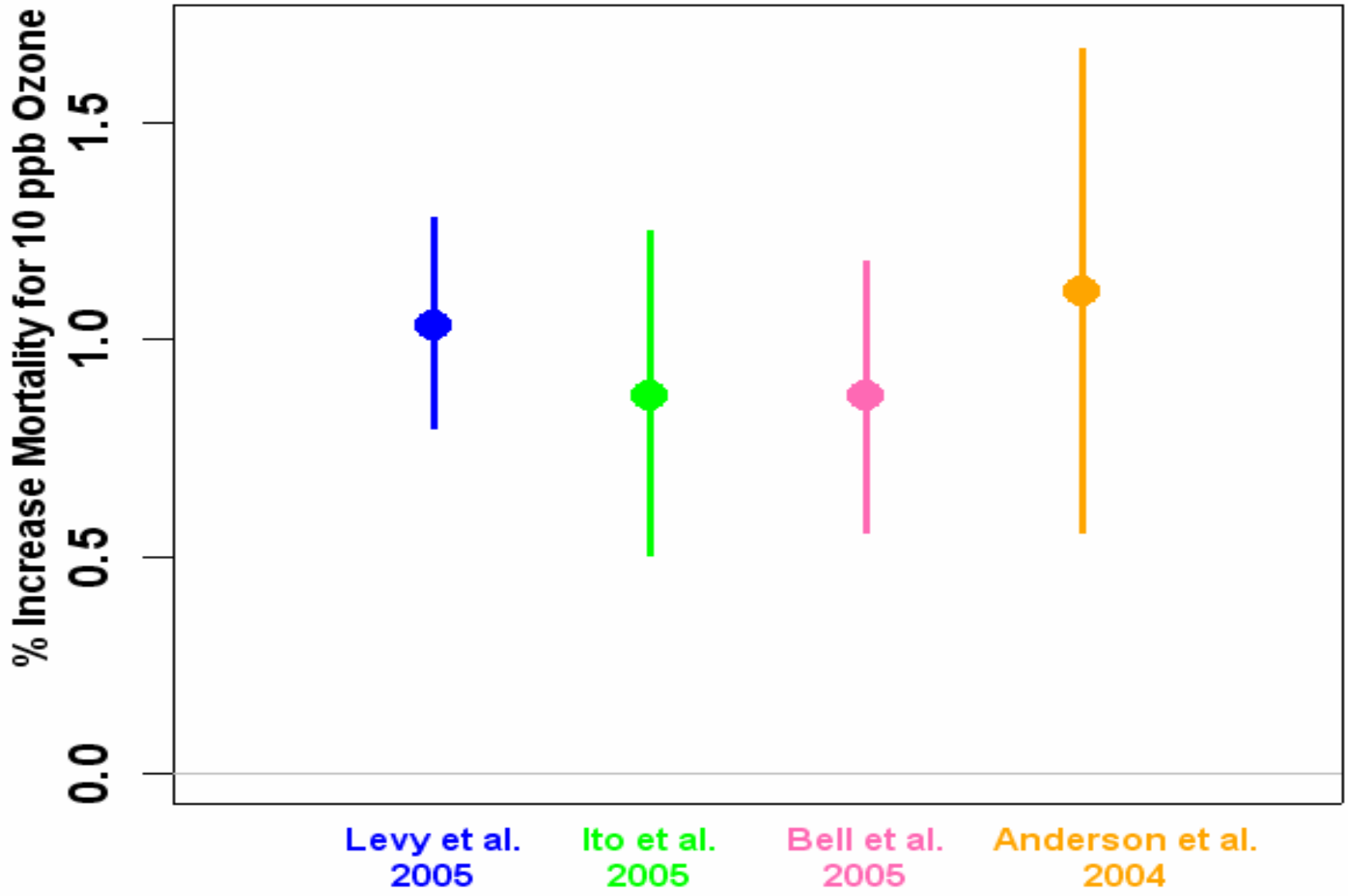
Bell et al. *Epidemiology* 2005

Results by Cause

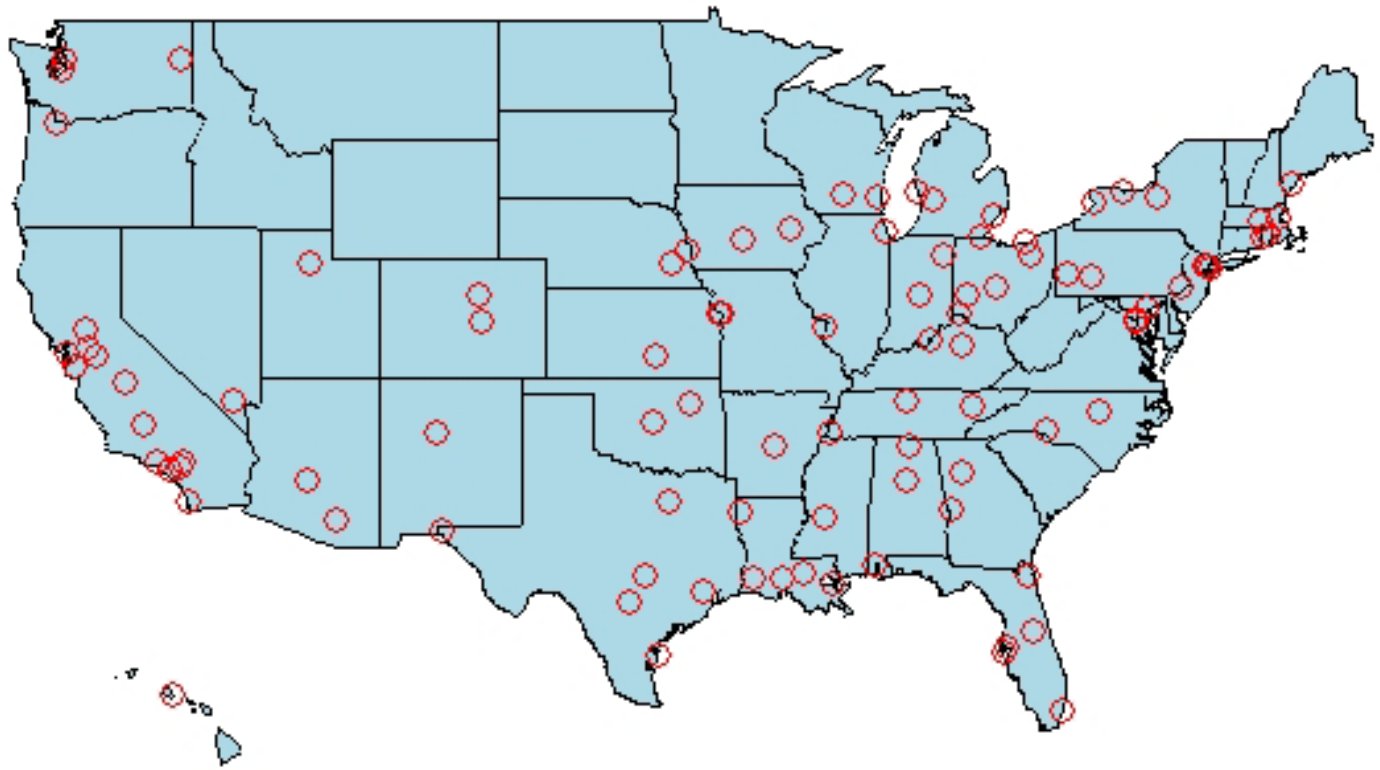
- Percent increase in daily total mortality for a 10 ppb increase in daily ozone (95% PI)

- Total: **0.87% (0.55, 1.18%)**
- CVD: **1.11% (0.68, 1.53%)**
- Respiratory: **0.47% (-0.51, 1.47%)**

Comparison of Meta-Analyses Results



O_3 Multi-City Time-Series



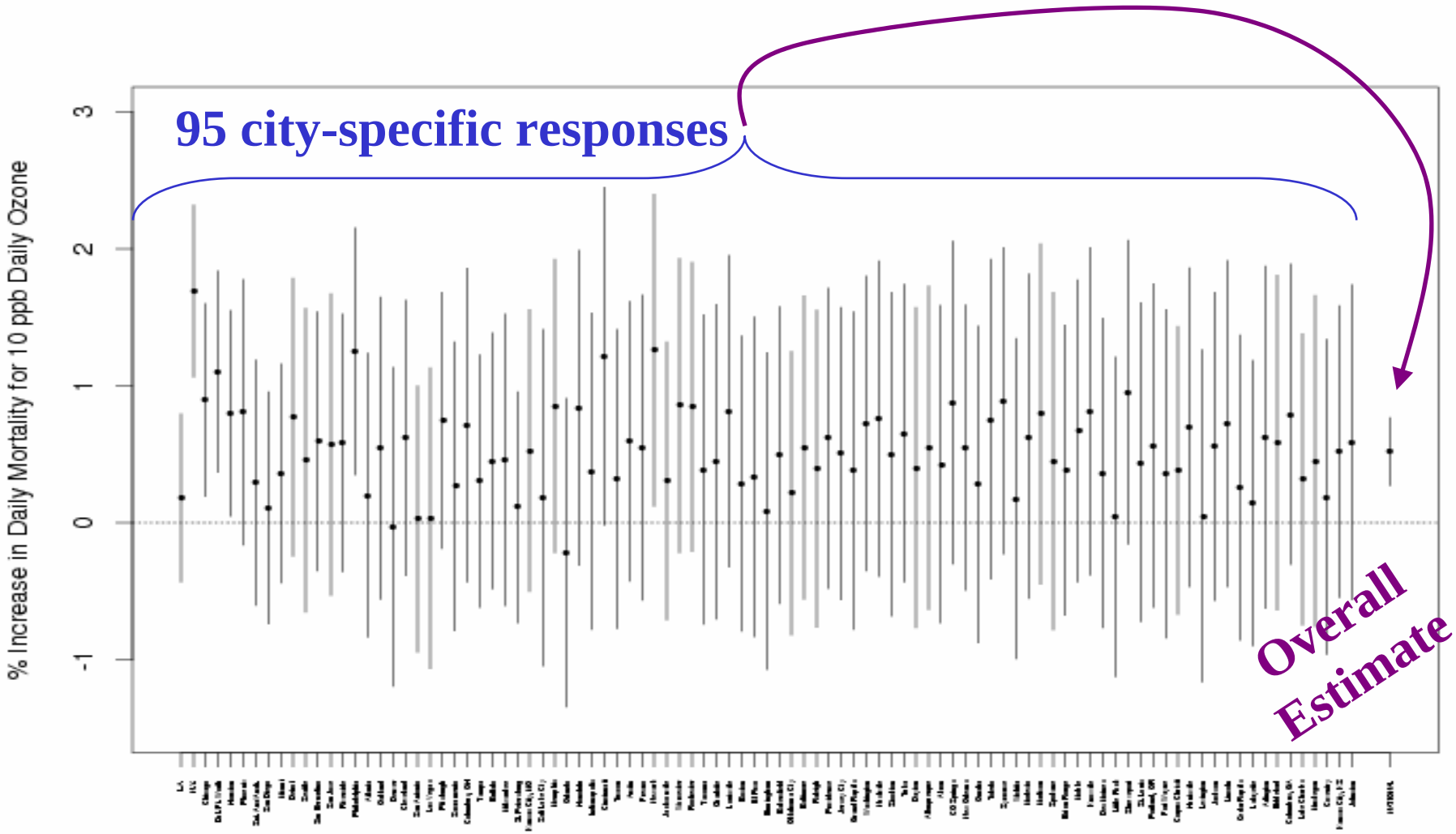
95 U.S. urban centers (1987 to 2000)

Bell et al. JAMA (2004)

Hierarchal Approach

1) Estimate the community-specific relationship between ozone and mortality, adjusted for:
   - Day of the week
   - Weather (temperature, dew point temperature, heat waves)
   - Long-term trend and seasonality
2) Combine the community-specific estimates, accounting for their uncertainty, to generate an overall effect

Community-Specific Bayesian Estimates



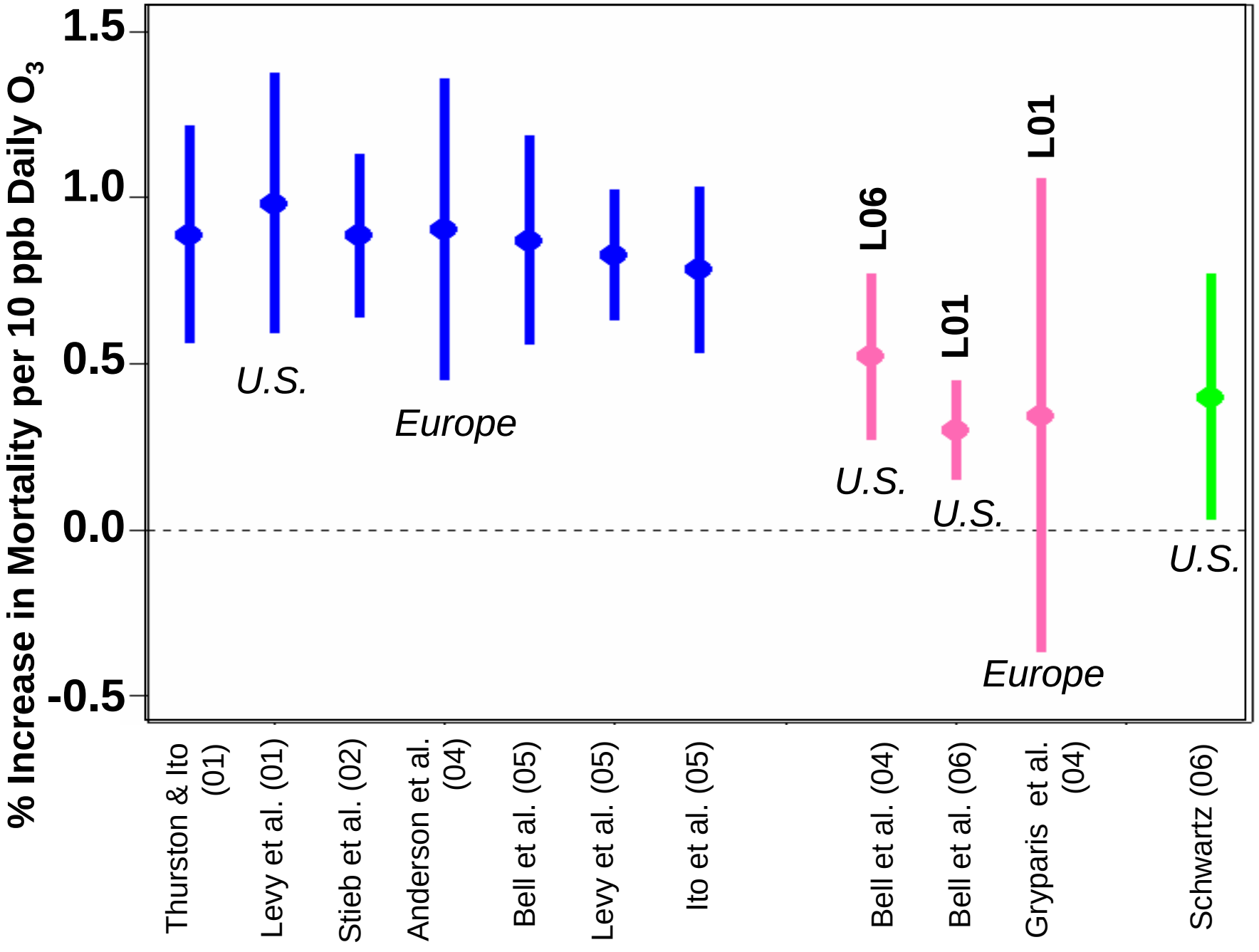
Bell et al. JAMA (2004)

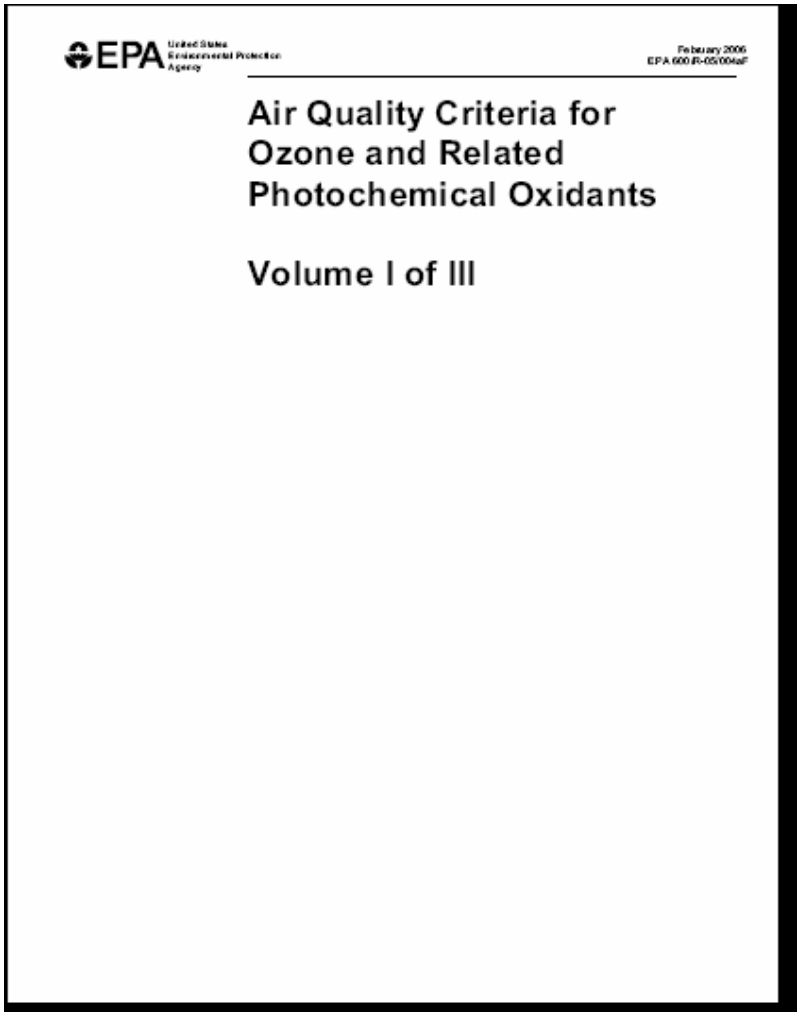
O_3 Multi-City Time-Series

- Gryparis et al. (2004) *AJRCCM*
  - APHEA2
  - Increase in mortality per 10 μg/m^3 L01 1-hr max (n=23)
    - Total: 0.10 (-0.11 to 0.26%)
    - Total: 0.33% (0.17 to 0.52%), warm season
    - Total: 0.27% (0.10 to 0.47%) (n=19), warm season with PM_{10}
    - CVD: 0.45% (0.22 to 0.69%), warm season
    - Resp: 1.13% (0.62 to 1.48%), warm season

O_3 Case-Crossover

- Schwartz (2005) *AJRCCM*
  - Case-crossover approach: Each person acts as his/her own control
  - Match: all other days of the same month and same year
  - Increase in mortality for 10 ppb 1-hr max ozone
    - 0.19% (0.03 to 0.35%) (n=14)
    - 0.19% (0.03 to 0.36%) with PM_{10} as covariate
    - 0.23% (0.01 to 0.44%) with temperature matched controls


% Increase in Mortality per 10 ppb Daily O_3
1.5
1.0
0.5
0.0
-0.5
U.S.
Europe
L06
U.S.
L01
U.S.
L01
Europe
U.S.
Thurston & Ito (01)
Levy et al. (01)
Stieb et al. (02)
Anderson et al. (04)
Bell et al. (05)
Levy et al. (05)
Ito et al. (05)
Bell et al. (04)
Bell et al. (06)
Gryparis et al. (04)
Schwartz (06)



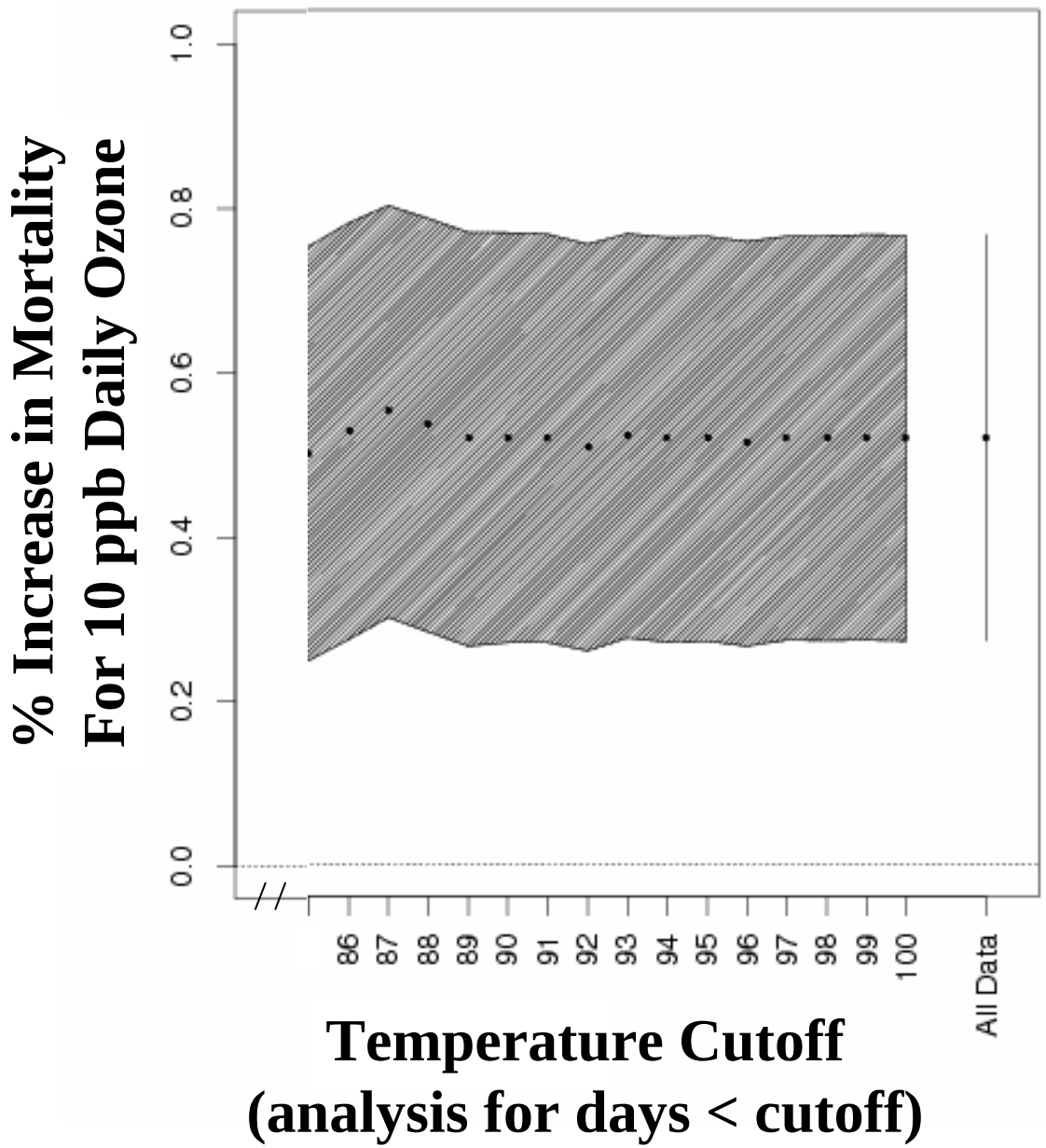
Mortality now included as a health endpoint for ozone.

Source: EPA. *Air Quality Criteria for Ozone and Related Photochemical Oxidants*. **2006**

Confounding by temperature?

- Meta-analyses accounting for non-linear relationship between weather and mortality
- Control for weather in time-series models
- Case-crossover matching on temperature

Exclude High Temperature Days



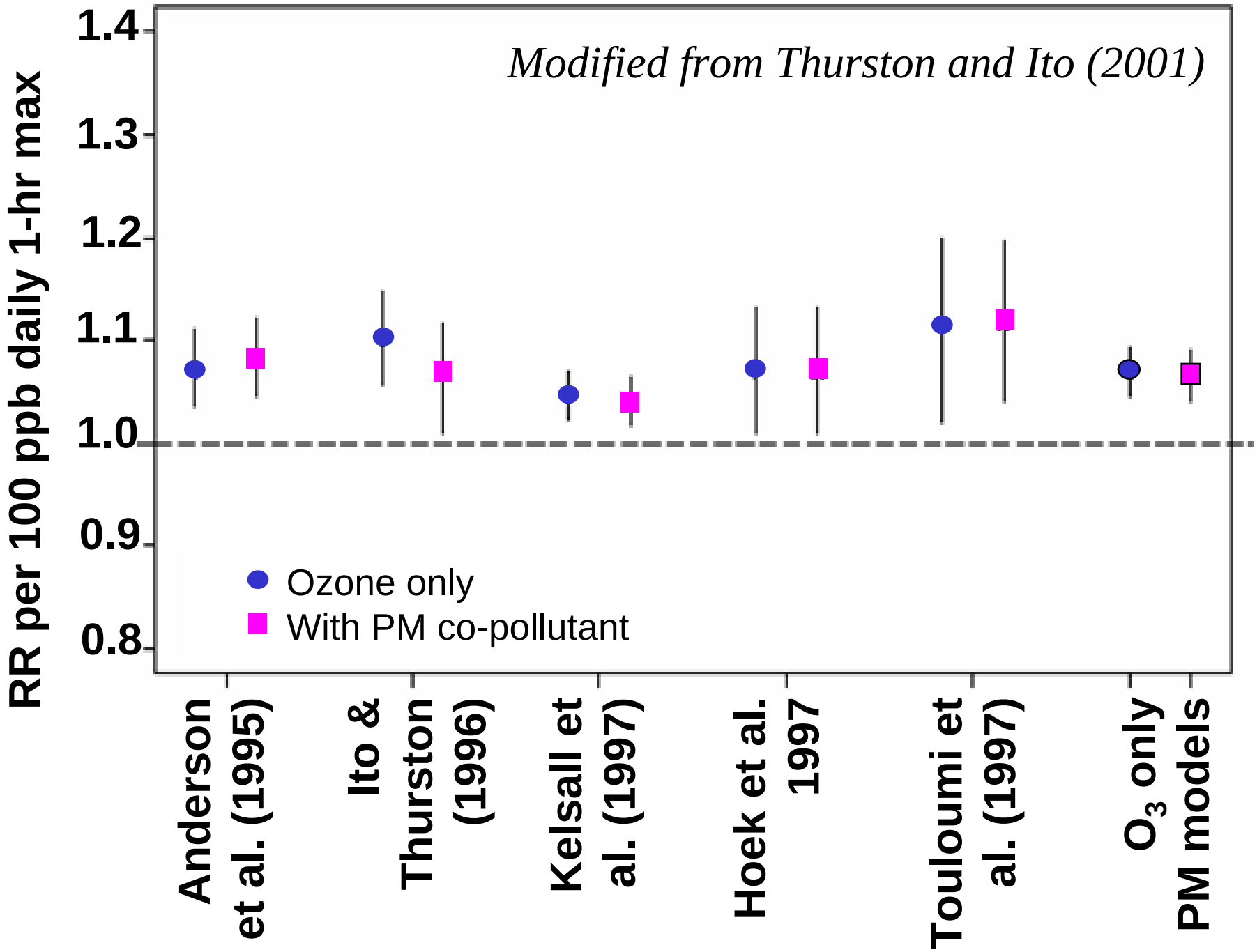
- Results robust to exclusion of high temperature days

- Effects range from:
  0.50% (0.25, 0.75%)
  to
  0.55% (0.30,0.80%)

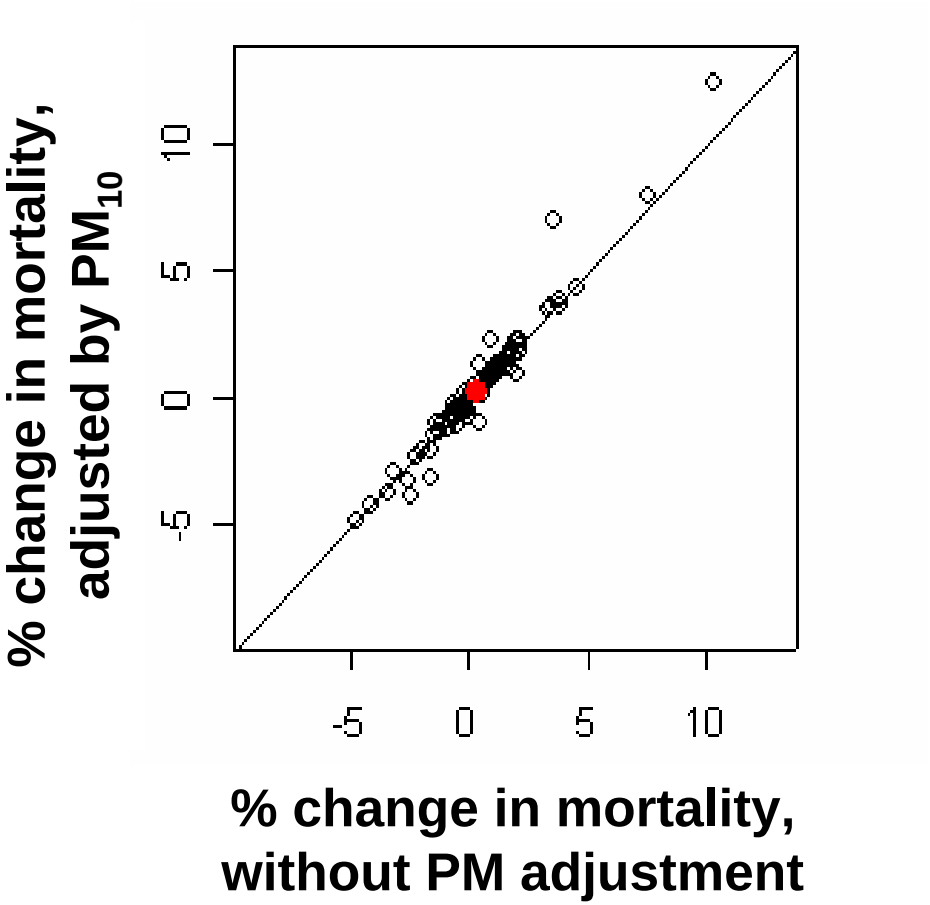
Bell et al. JAMA (2004)

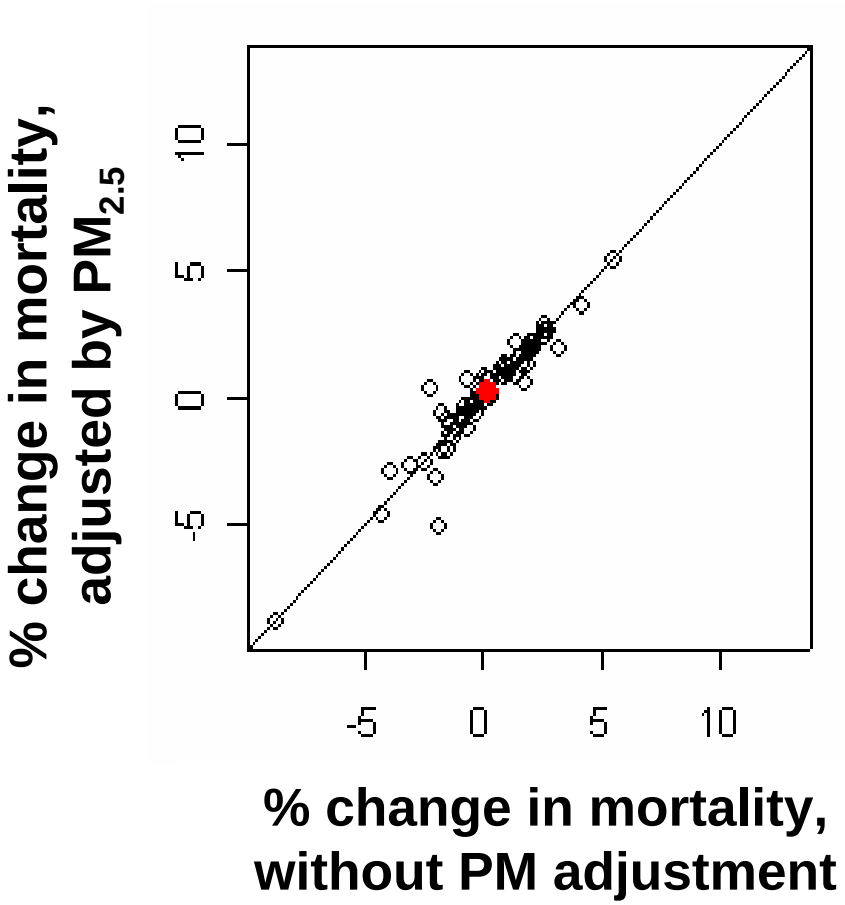
Confounding by PM?

- O_3 estimates robust to inclusion of PM
  - Meta-analysis
    - Thurston and Ito (2001)
    - Stieb et al. (2002)
    - Bell et al. (2005)
    - Ito et al. (2005)
  - Multi-city time series
    - Bell et al. (2004)
    - Gryparis et al. (2004)
  - Case-crossover
    - Schwartz et al. (2006)


Modified from Thurston and Ito (2001)
RR per 100 ppb daily 1-hr max
1.4
1.3
1.2
1.1
1.0
0.9
0.8
Ozone only
With PM co-pollutant
Anderson et al. (1995)
Ito & Thurston (1996)
Kelsall et al. (1997)
Hoek et al. 1997
Touloumi et al. (1997)
O3 only PM models

Sensitivity to Adjustment by PM

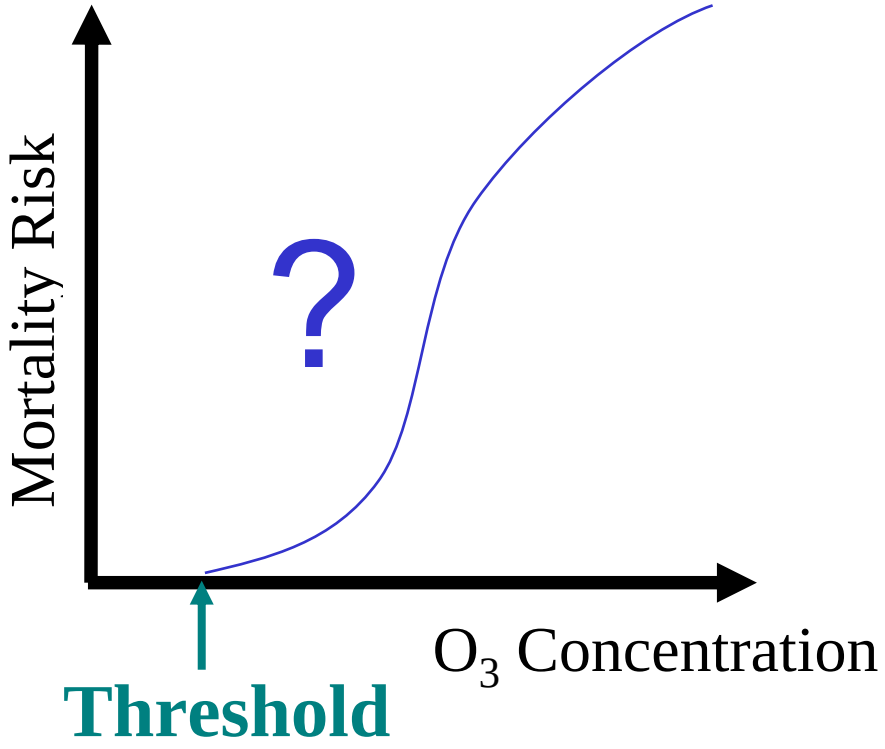




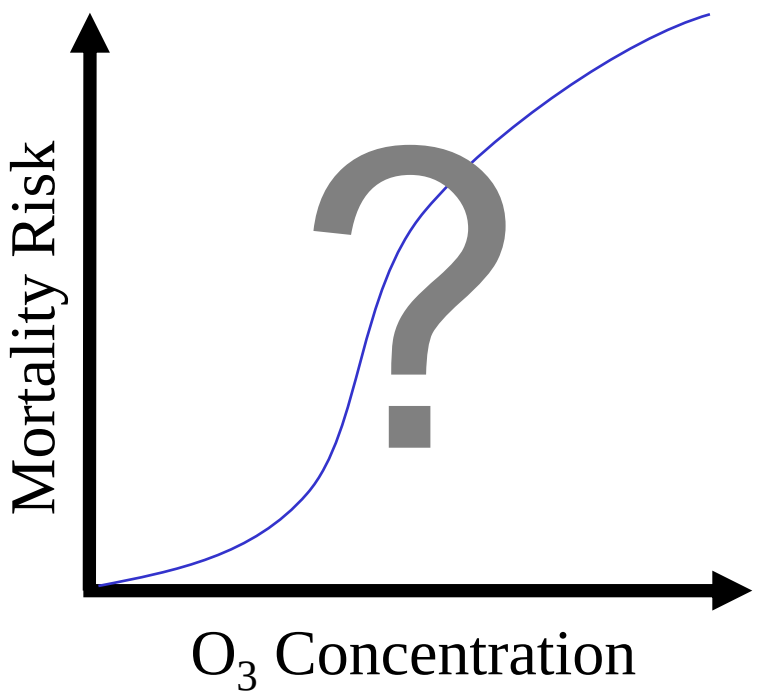
(Bell, Kim, and Dominici)

Threshold Effect for O_3

- What is the shape of the exposure-response curve for ozone?
- Are there “safe” levels?
- What are effects at low concentrations?



Exposure-response curve models

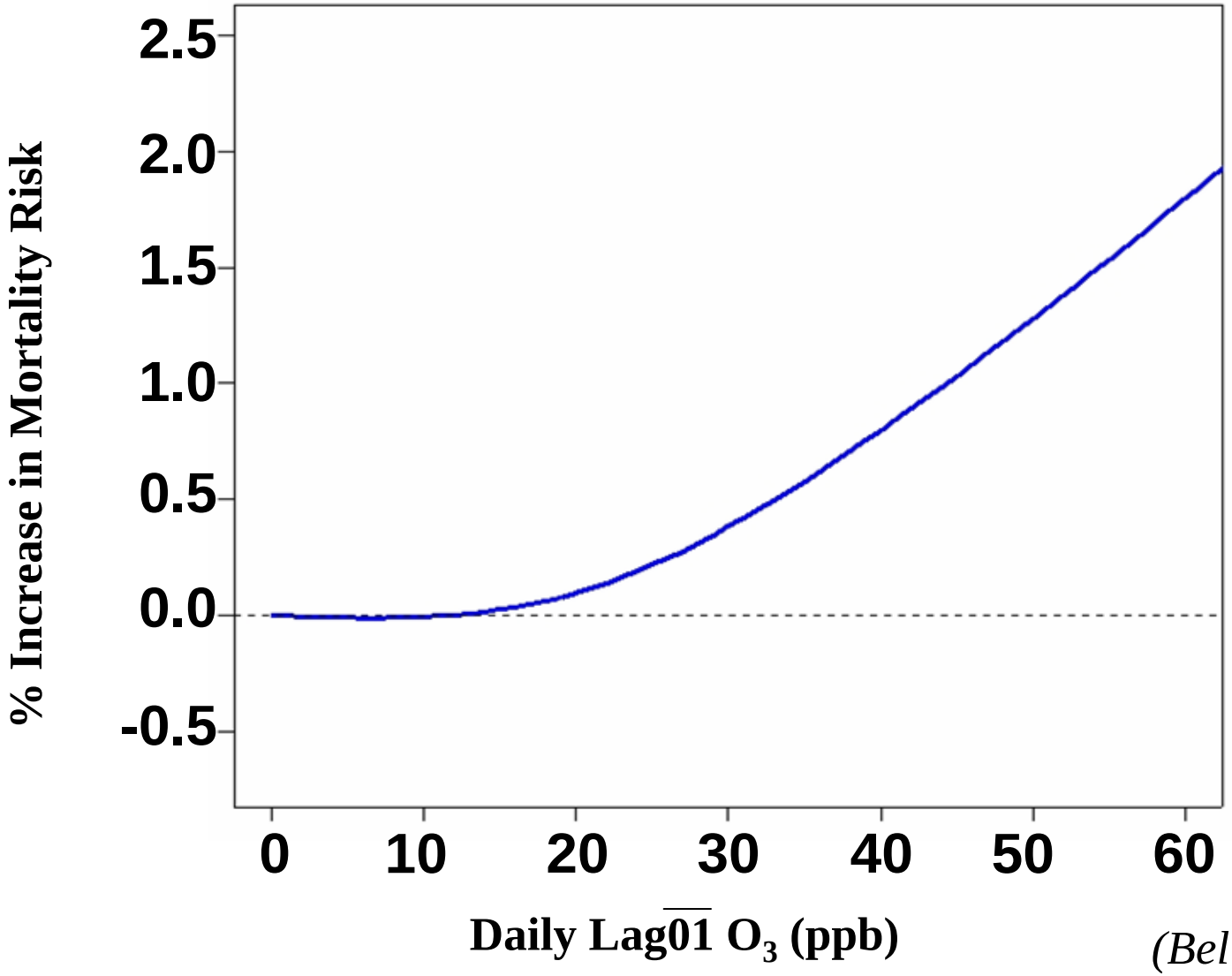


Four model structures:

1) Traditional model
2) Subset approach
   - Only consider days with ozone < *s*
3) Threshold model
   - Only allow relationship at ozone $\geq h$
4) Spline model
   - Allow non-linear relationship

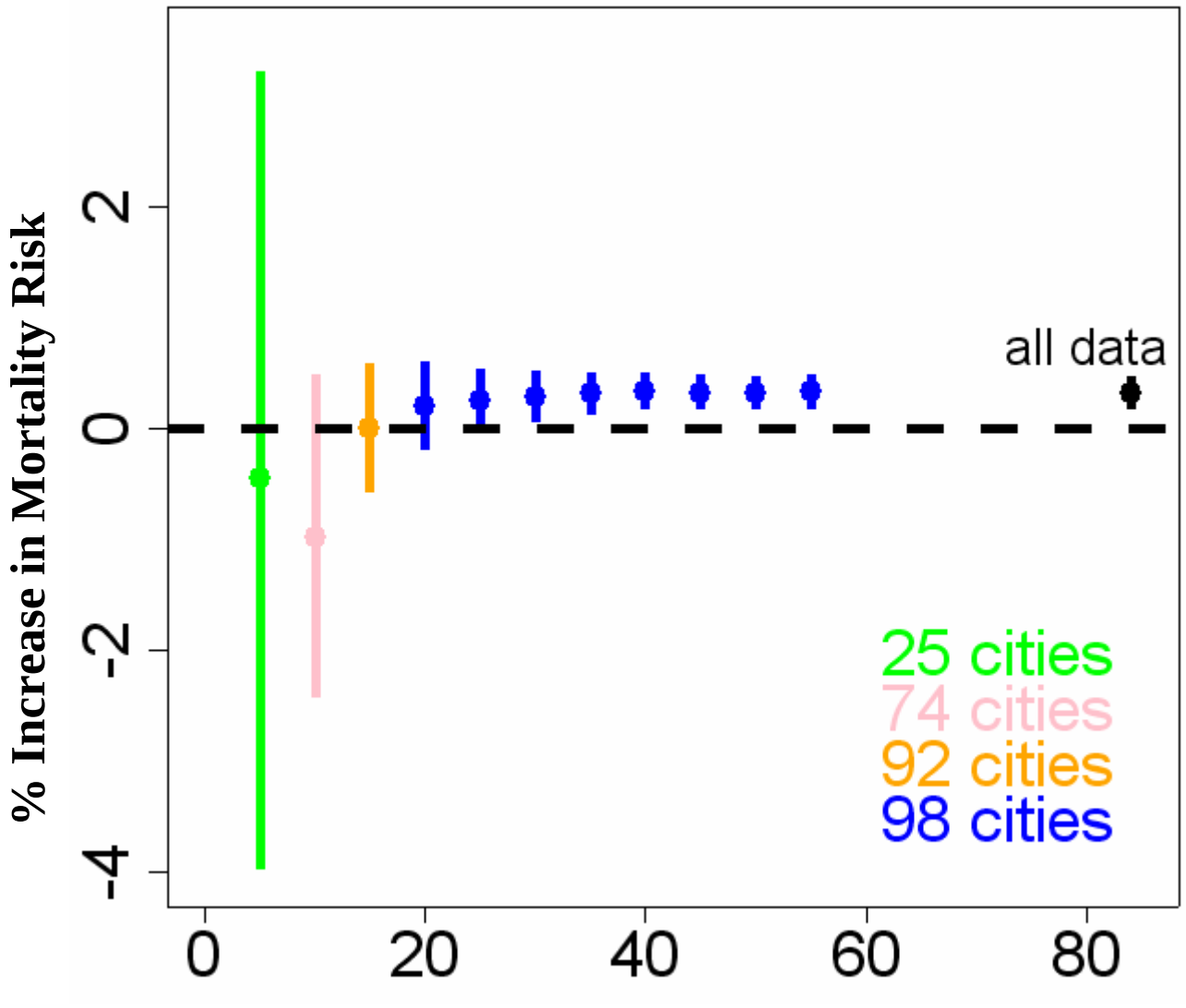
Bell et al. (2006)

Results - Spline Model



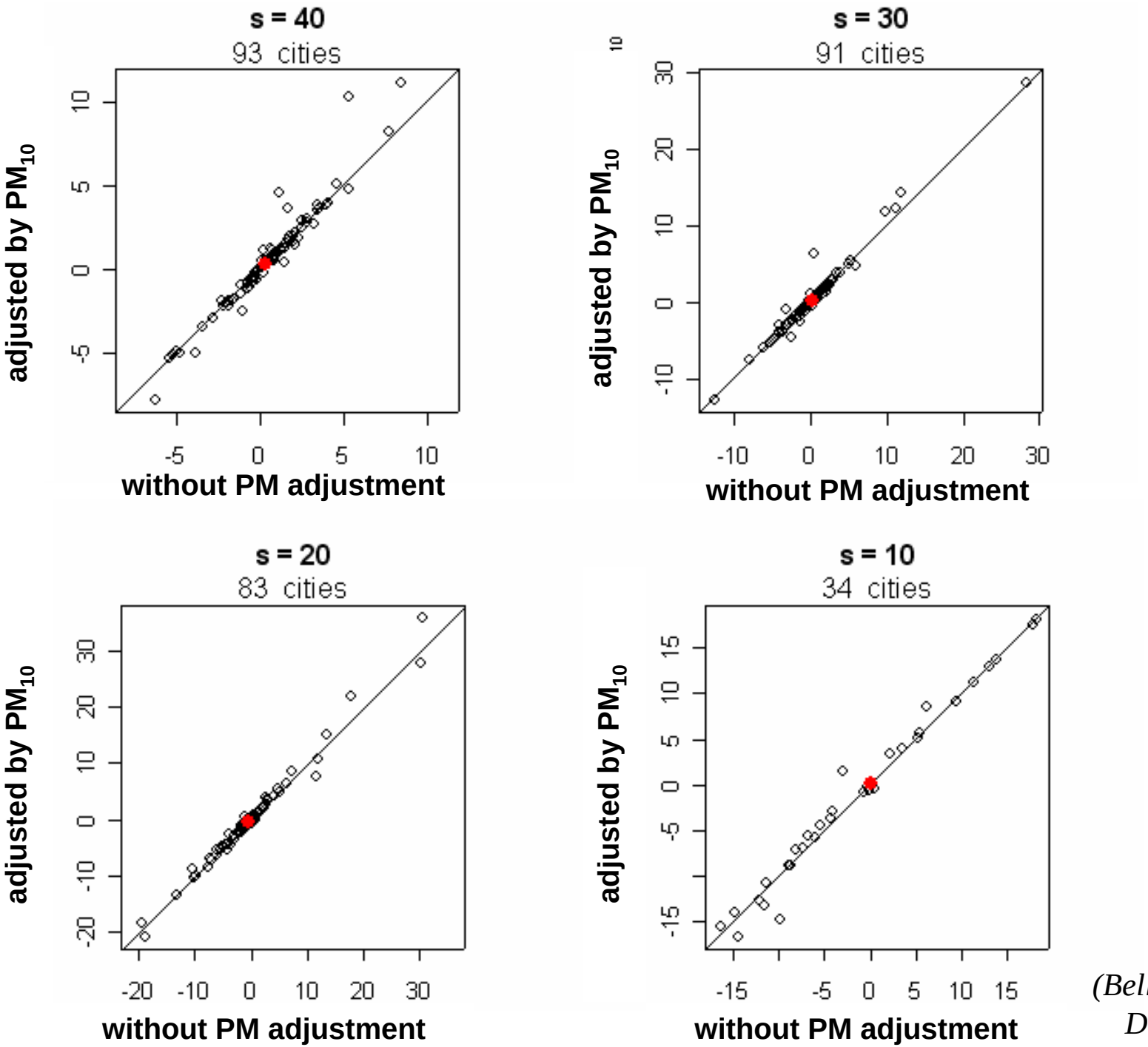
(Bell et al. 2006)

Results – Subset Approach



s: for daily Lag $\overline{01}$ O_3 (ppb)

Bell et al. (2006)



(Bell, Kim, and Dominici)

Final Thoughts

- Strong, consistent evidence of an association between short-term exposure to ozone and increased risk of mortality from multiple study designs.
- Results do not appear to be confounded by PM or temperature.
- Effects persist at low concentrations.

References

Meta-Analysis Studies

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Commentaries on 2005 Meta-Analyses

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Case-Crossover Study

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Multi-City Studies

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