Supplemental Materials

S.1 Average Population-Weighted Concentrations – Modeling Results Analysis by Resolution

With the exception of Boston, the differences in ozone production in large cities (areas associated with large and heterogeneous population density: Atlanta, Boston, Washington DC, Detroit, Houston, and New York City) are more sensitive to model resolution than ozone production in areas with smaller and more homogeneous population densities (New York, Western Pennsylvania and Virginia), as shown in Figure S.1. Population weighted ozone results modeled at 12 km resolution are similar to 4 km resolution for each of the nine regions. Coarse resolution modeling (36 km) allows for maximum chemistry over the largely population areas by including more emissions sources, which are assumed (by nature of this modeling process) to be perfectly mixed. Maximum chemistry causes the model to estimate the largest decrease due to the control policy. In the fine resolution modeling (12 and 4 km), emissions of ozone precursors that are released in areas of high population density (NOx from vehicles for example) are transported to areas of less population density before they are well mixed with VOCs in order to form ozone.

Interpretation of the change in population-weighted total $PM_{2.5}$ concentration is complicated because unlike ozone, which is only one species, PM is made up of many different species. Some PM species are secondary species (similar to ozone) and therefore production may be enhanced by large perfectly mixed grid cells containing many emissions sources. Particulate sulfate and nitrate are some examples. Emissions of nitrogen oxides and sulfur dioxide react with ammonium in the atmosphere to form particulates. These reactions are likely to be maximized (and therefore the impacts of emissions reductions maximized) in coarse resolution models.

This is in contrast to primary PM species where in fine resolution modeling, direct emissions are diluted less than in coarse resolution modeling. Therefore decreases in emissions of primary PM will lead to larger decreases in the concentration of those primary PM species when the model resolution is finer.

The combined impact of primary and secondary species in PM modeling is the reason why there is no clear pattern emerging in the population weighted concentrations of $PM_{2.5}$ when estimated using three different model resolutions, as shown in Figure S.2.

S.2 Mortality Impacts by Region: Modeling Results by Resolution

S.2.1 Boston

Boston mortality impacts show little variability by resolution and by species. Changes in mortality due to changing concentrations of ozone and $PM_{2.5}$estimated using coarse scale modeling results are 2% larger and 8% smaller respectively than corresponding finer scale estimations as shown in Figures S.3 a and b.

S.2.2 Washington DC

The change in mortality due to changes in ozone calculated using 36 km model resolution are 40% larger than the change in ozone mortality estimated using 12 km resolution modeling. For $PM_{2.5}$, the difference in the mortality changes due to PM concentration changes is 3% larger using 36 km results versus 12 km results, and 0.1% smaller versus 4 km results. These results are shown in Figure S.4. a and b.

S.2.3 Detroit

Detroit, similar to Houston and New York City, showed large sensitivity to resolution when estimating ozone mortality. The point estimate for avoided ozone mortality obtained using 36 km modeling resolution results fell outside the uncertainty range of the finer resolution mortality results. This finding indicates that modeling ozone human health impacts in Detroit at coarse scale resolution has the potential to over-estimate benefits associated with reductions by 100%. In Detroit the changes in mortality due to $PM_{2.5}$ emissions changes calculated using coarse scale modeling are 10% smaller than results calculated using finer scale modeling. Detroit Mortality results are shown in Figs. S.5. a and b.

S.2.4 Houston

Houston, similar to Detroit and New York City, shows large sensitivity to resolution when estimating ozone mortality. The point estimate for avoided ozone mortality obtained using 36 km modeling resolution results fell outside the uncertainty range of the finer resolution mortality results. This finding indicates that modeling ozone human health impacts in Houston at coarse scale resolution could severely over-estimate benefits associated with reductions (in this study, 36 km mortality benefits were nine times larger than benefits estimated using finer scale results). $PM_{2.5}$ health benefits calculated using 36 km modeling results were at most 8% larger than results calculated using finer scale modeling. Houston mortality results are shown in Figs. S.6. a and b.

S.2.5 New York State

Mortality changes calculated in a rural area of New York State show low sensitivity to model resolution for both ozone and $PM_{2.5}$ as shown in Figs. S.7. a and b. Changes in mortality due to changes in concentrations estimated using 36 km modeling results were 9% larger than benefits estimate using finer scale modeling results for ozone. Mortality changes due to changes in $PM_{2.5}$ concentrations estimated using 36 km modeling results were and 7% larger than 12 km results and 9% smaller than 4 km results.

S.2.6 New York City

New York City, like Detroit and Houston, shows large sensitivity to resolution when estimating ozone mortality. The point estimate for avoided ozone mortality obtained using 36 km modeling resolution results fell outside the uncertainty range of the finer resolution mortality results. This finding indicates that modeling ozone human health impacts in New York City at coarse scale resolution could potentially over-estimate benefits associated with reductions by 250%. Mortality point estimates from $PM_{2.5}$ in New York City are at most 7% smaller when calculated using coarse scale modeling versus fine scale modeling. Mortality results for New York City as shown in Figs. S.8. a and b.

S.2.7 Western Pennsylvania

Mortality changes calculated for Western Pennsylvania show low sensitivity to model resolution for both ozone and $PM_{2.5}$ as shown in Figs. S.9. a and b. Human health benefits estimated using 36 km modeling results were 14% and 3% larger than benefits estimate using finer scale modeling results for ozone and $PM_{2.5}$ respectively.

S.2.8 Virginia

Mortality changes calculated for rural Virginia show low sensitivity to model resolution for both ozone and $PM_{2.5}$ as shown in Figs. S.10. a and b. Human health benefits estimated using 36 km modeling results were 1% and 6% larger than benefits estimated using finer scale modeling results for ozone and $PM_{2.5}$ respectively.

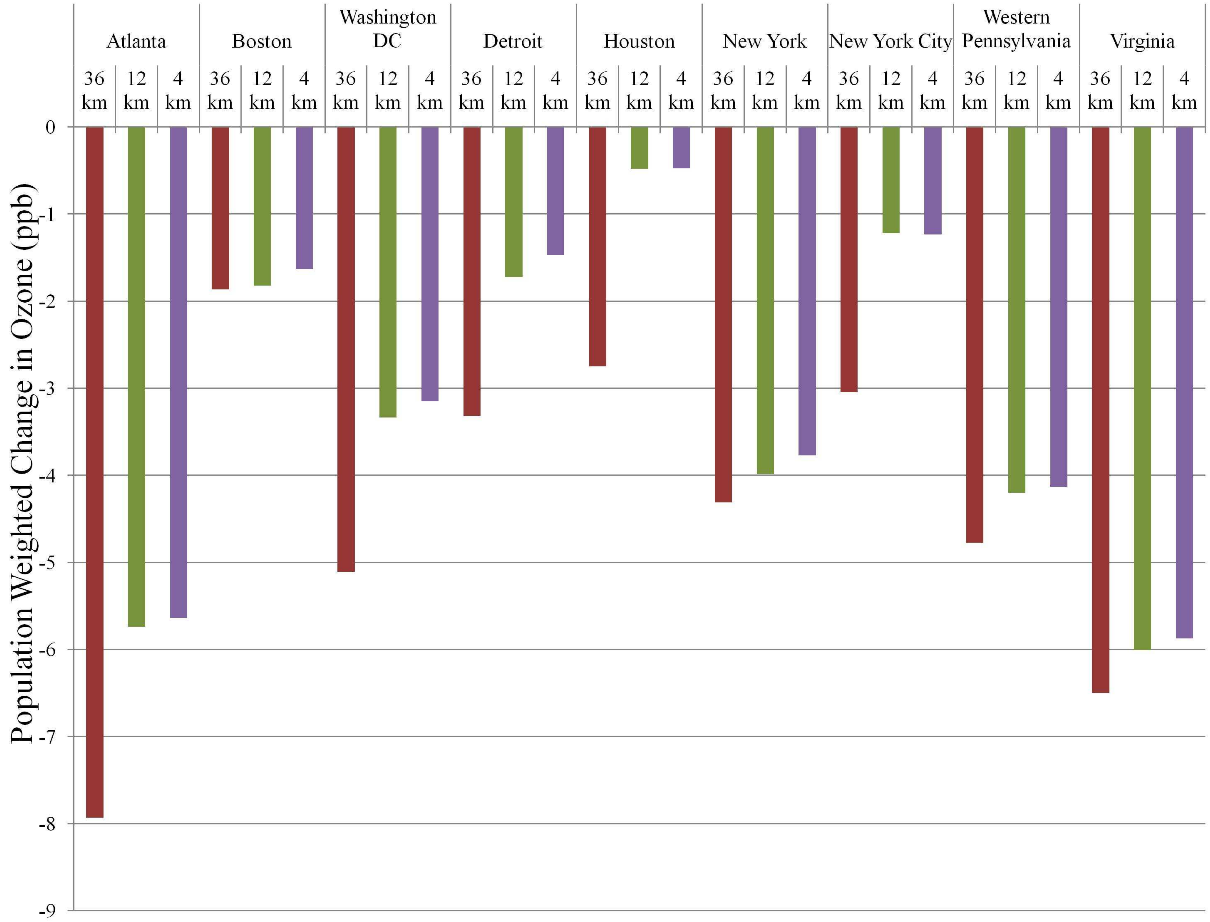

Figure S.1. Change in population weighted daily maximum 8 hr averaged ozone concentration calculated using results modeled at three resolutions in each of nine regions.

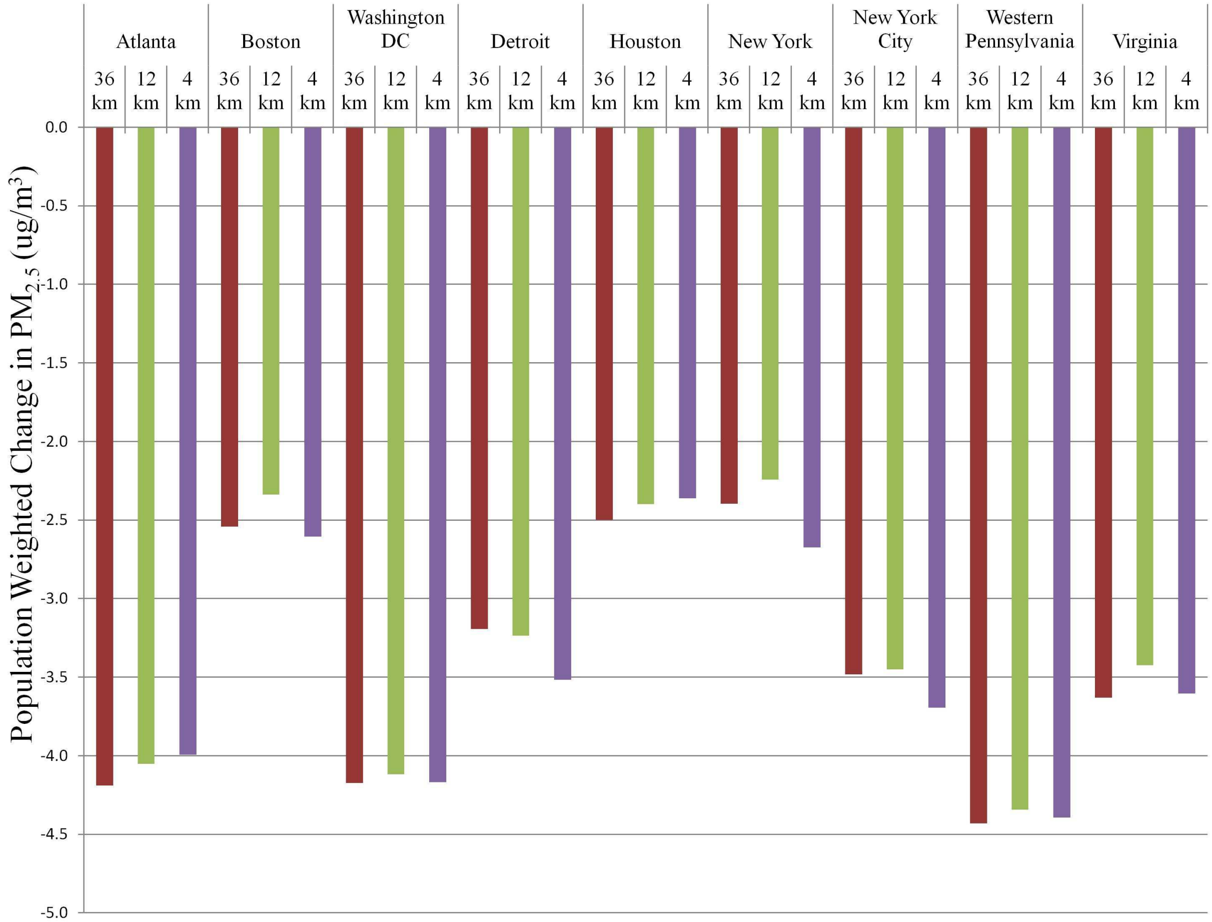

Figure S.2. Change in population weighted annual average $PM_{2.5}$ concentration calculated using results modeled at three resolutions in each of nine regions.

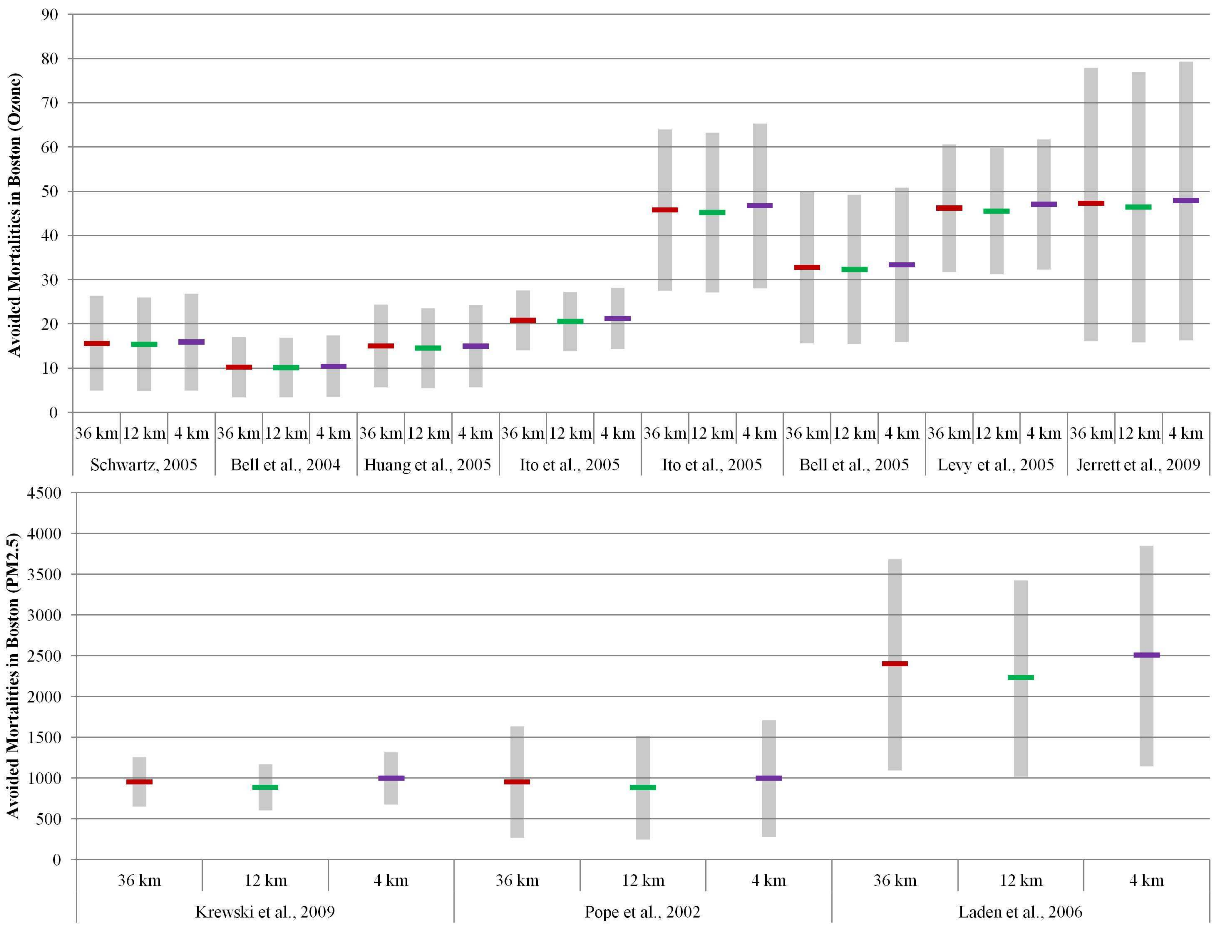

Figure S.3. a. Mortalities avoided in Boston due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b.** Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

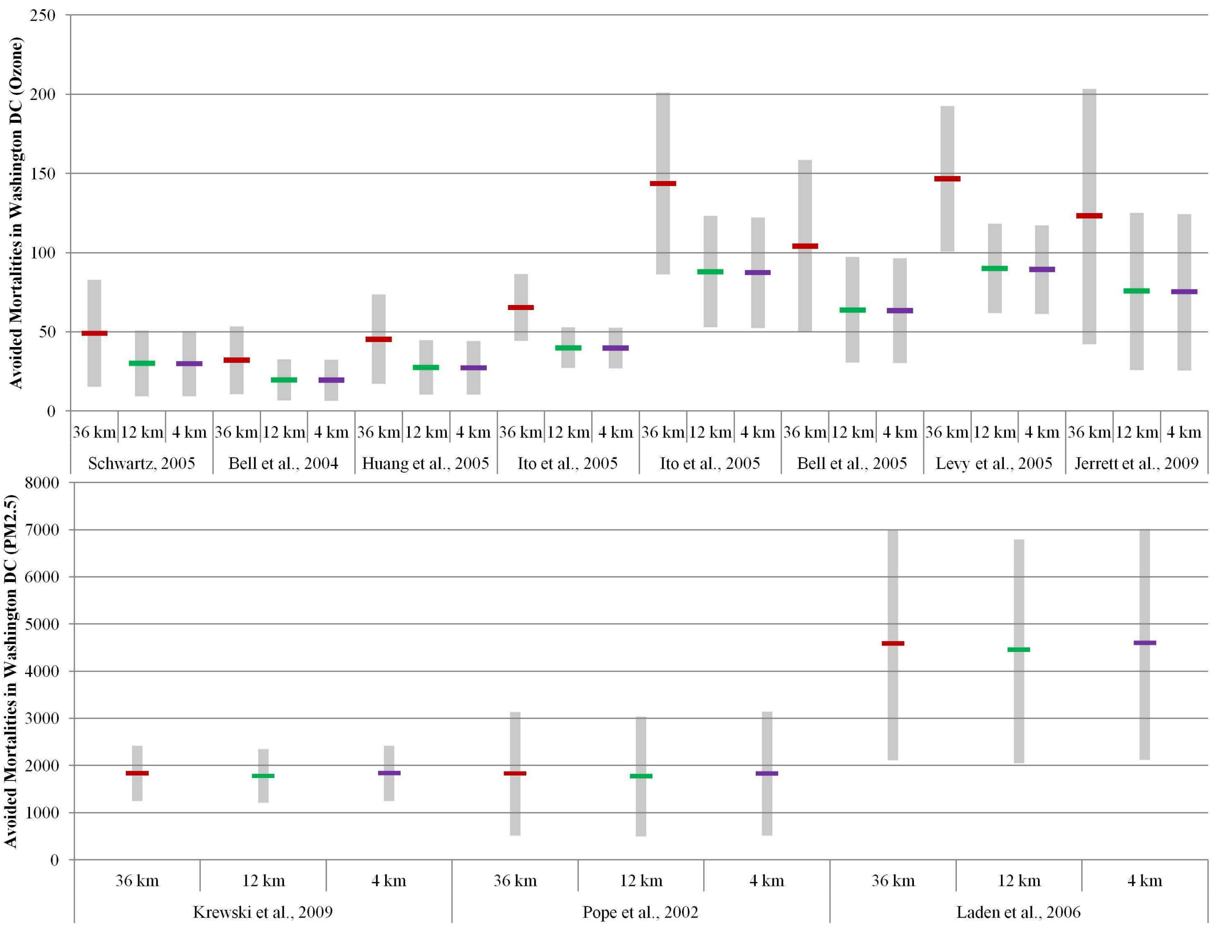

Figure S.4. a. Mortalities avoided in Washington DC due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b.** Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

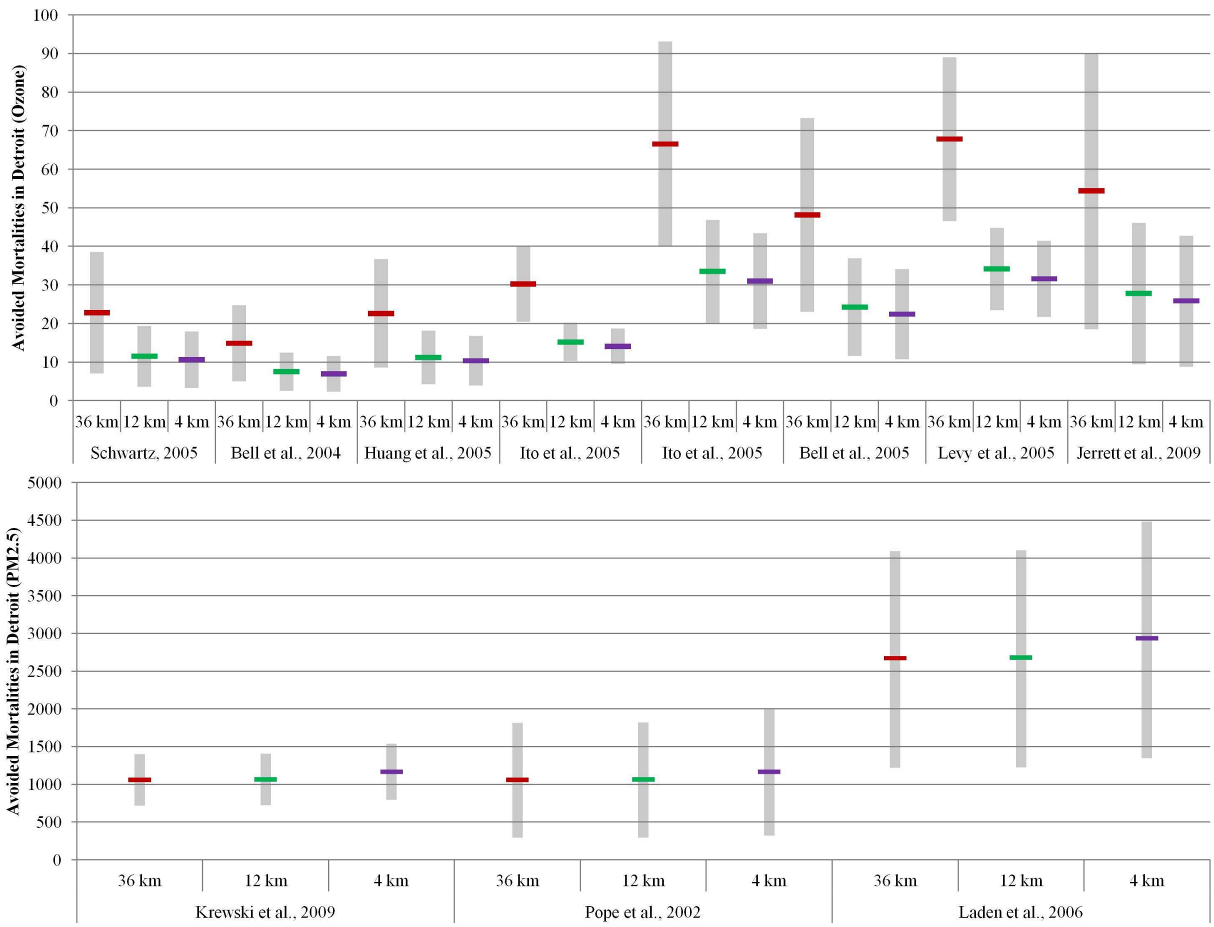

Figure S.5. a. Mortalities avoided in Detroit due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b.** Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

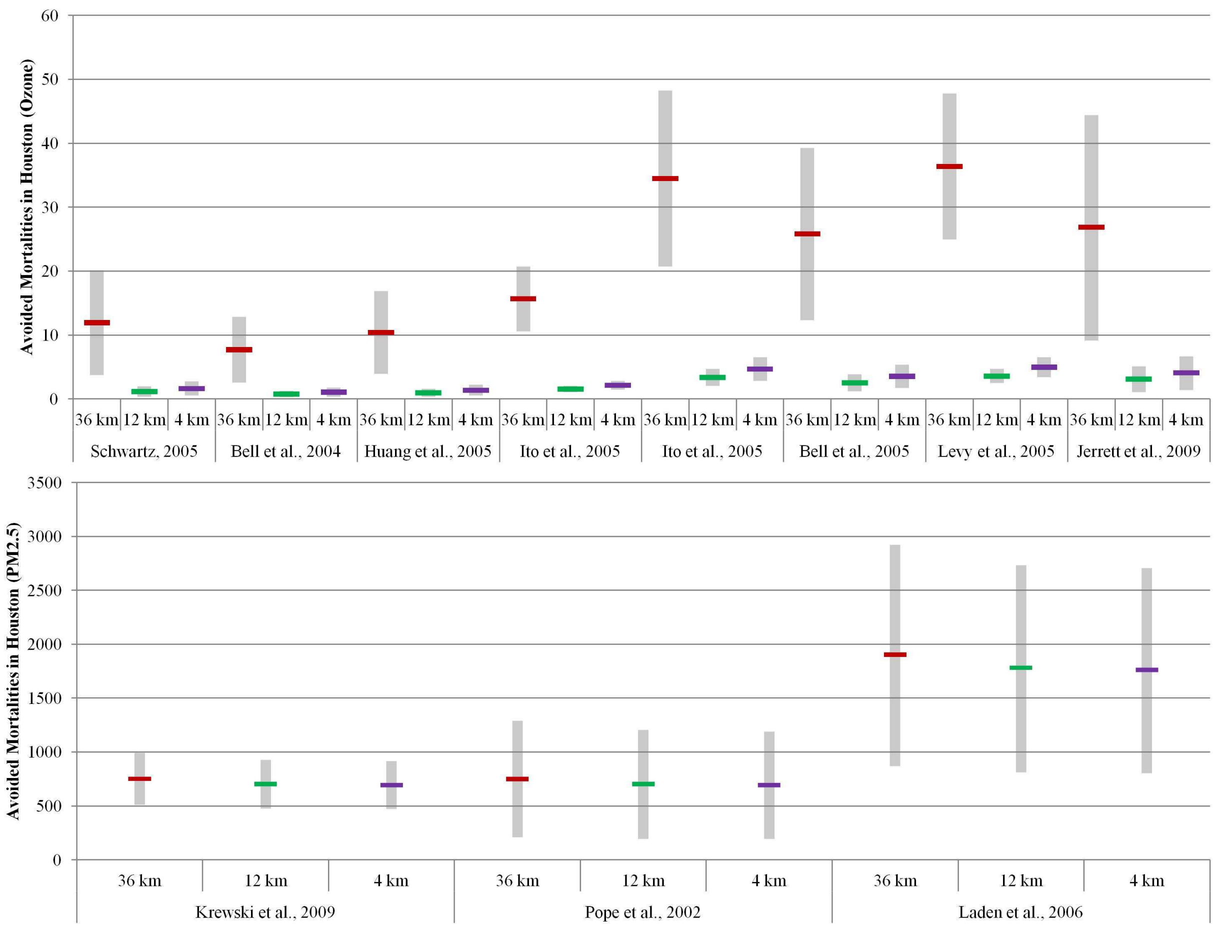

Figure S.6. a. Mortalities avoided in Houston due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b**. Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

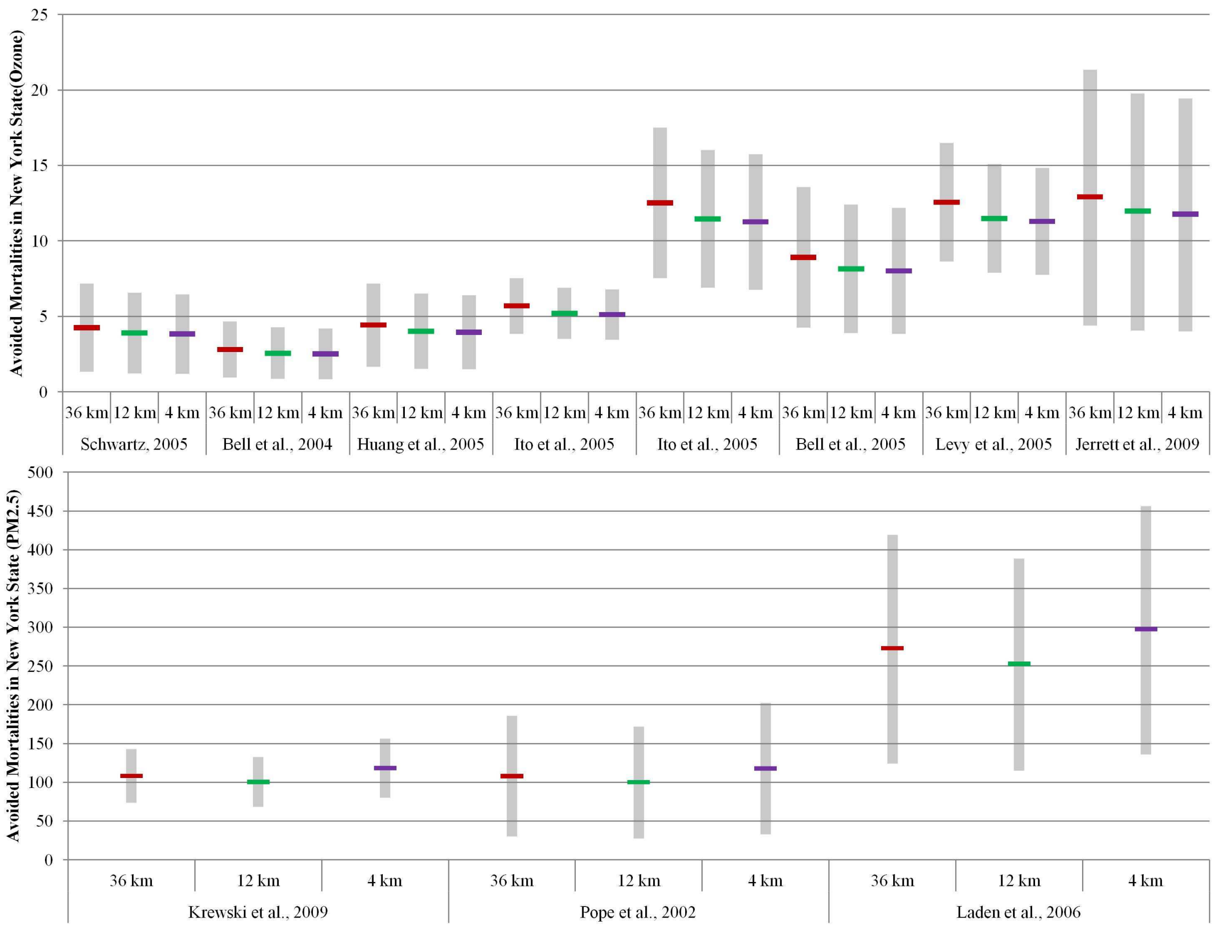

Figure S.7. a. Mortalities avoided in New York State due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b**. Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

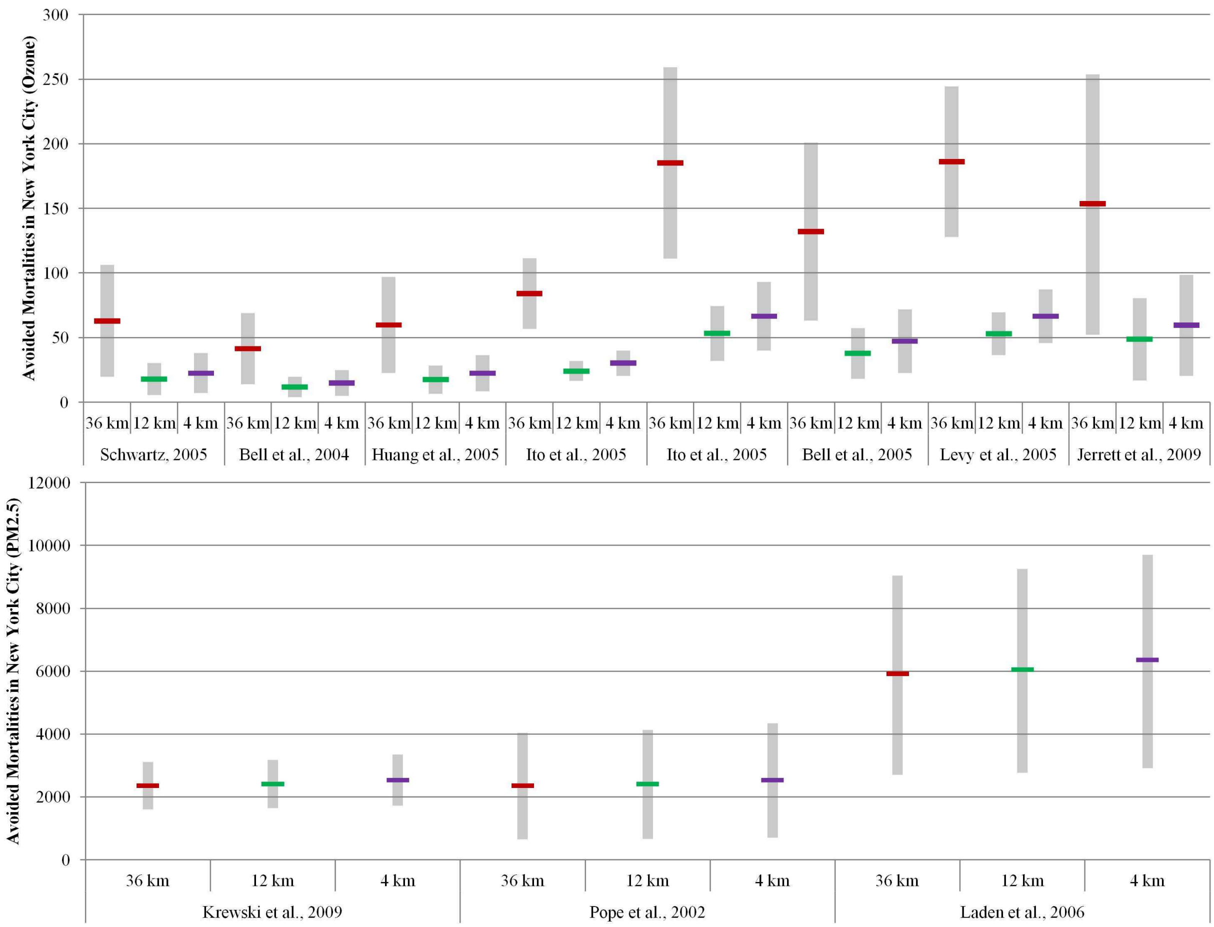

Figure S.8. a. Mortalities avoided in New York City due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b.** Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

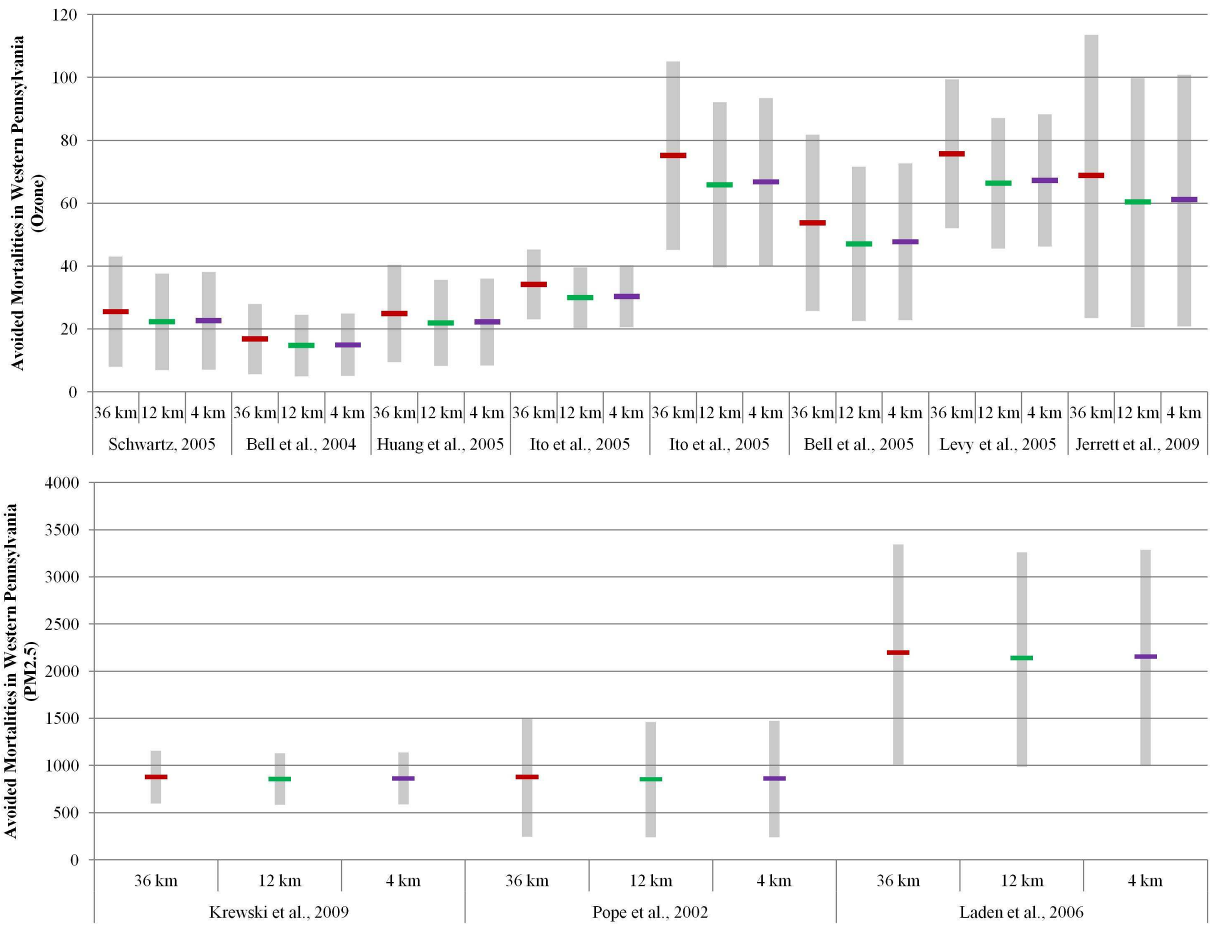

Figure S.9. a. Mortalities avoided in Western Pennsylvania due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b.** Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.

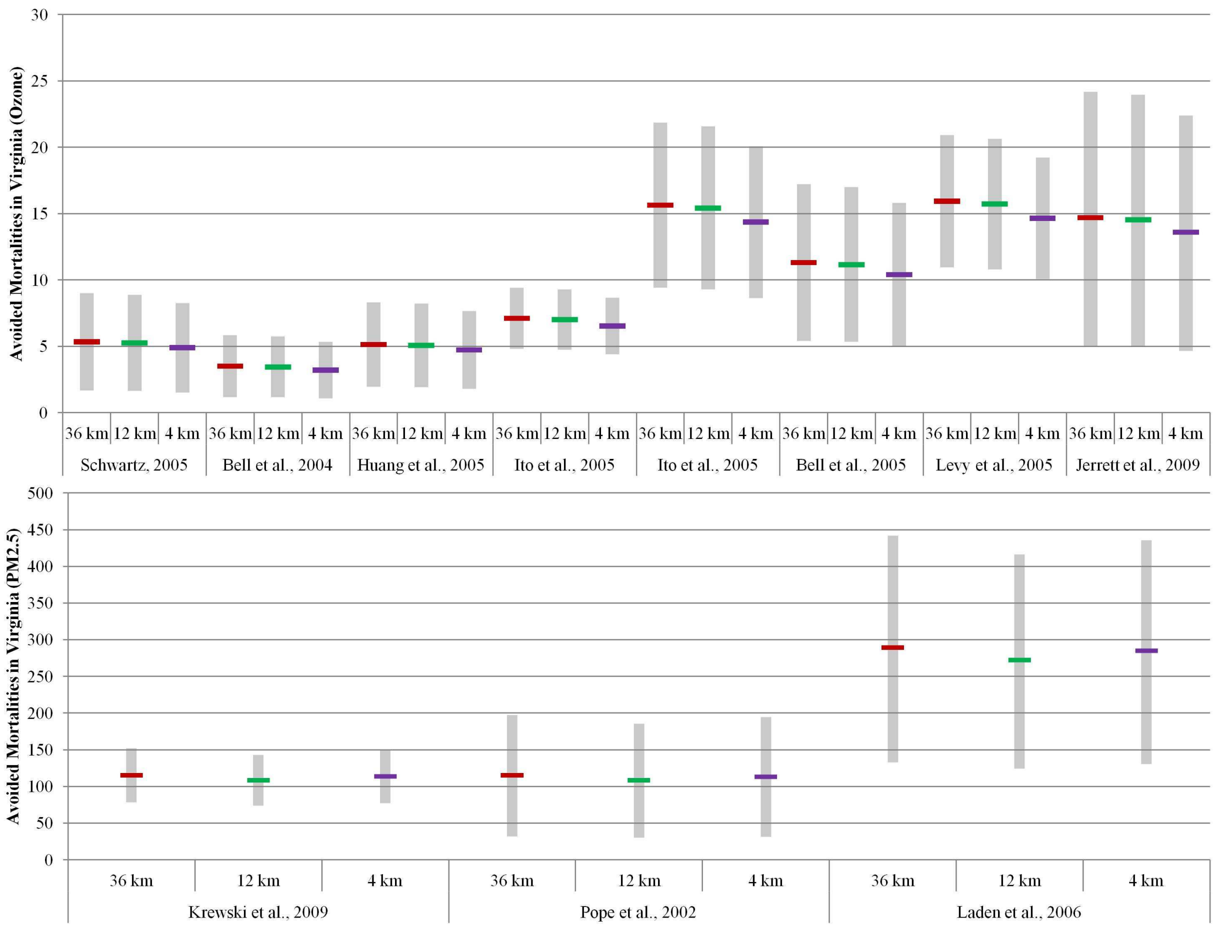

Figure S.10. a. Mortalities avoided due to changes in ozone concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using eight different concentration response functions. **b.** Mortalities avoided due to changes in $PM_{2.5}$ concentrations between the 2005 base case and the 2014 control case for each model resolution (red = 36 km, green = 12 km, blue = 4 km), calculated using three different concentration response functions.