

Determining the Effects of Grid Resolution on Marginal Damages of BC Emissions as Quantified by Adjoint Sensitivities

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Component-Specific Health

Impacts



Percent increase in health effects estimates for cardiovascular hospitalizations (A) and respiratory hospitalizations (B) (Bell et al., 2009)



Where is it Coming From?



EPA AIRNow June 07, 2011



MODIS June 07, 2011



Adjoint Models

- Forward sensitivity analysis are source-based
- Adjoint method provides receptor-based sensitivities
- Main advantage of adjoint method over FD:
 - Quickly calculate sensitivities with respect to all model parameters (sources) at the same time.

Inputs/Sources

X







Outputs/Receptors



Cost Function for National Premature Deaths

$$J = \sum_{i=1}^{N} Mort_i * (1 - exp^{-\beta * C_{av,i}})$$

$$\frac{\partial J}{\partial C_{i,t}} = \frac{Mort_i}{T} * \beta * exp^{-\beta * C_{av,i}}$$

- Mort = gridded annual premature deaths in the US
- C_{av} = gridded annual average concentration

NI

- T = number of timesteps in a year
- i =grid cell index
- N= total number of grid cells for which cost function is calculated
- β = concentration response factor, 0.005827 (Krewski et al., 2009)
- t = timestep index

Forward Model Simulations



Forward simulations run from Dec. 21, 2006 to Dec. 31, 2007

Annual average BC concentration

Gridded annual premature deaths associated with exposure to BC



12,600 (8,600 - 16,500) total premature deaths

70

50

30

20

10



Sensitivity of BC Health Impacts - Definitions

- 12 1-week adjoint simulations performed for the first week of each month
- \$\frac{\partial J}{\partial E_{i,k}}\$ = Resulting sensitivities averaged and scaled to yearly
 \$\frac{\partial J}{\partial E_{i,k}}\$ * \$E_{i,k}\$ = Contributions: semi-normalized sensitivities with respect to emissions scaling factors
- $\frac{\partial J}{\partial E_{i,k}} * \frac{E_{i,k}}{J} * 100\%$ = Contribution percentage: fraction of contribution from sectoral emissions in a single grid cell to sum of sectoral contributions
- $\frac{E_{i,k}}{\sum E_{i,k}} * 100\%$ = Emission percentage: fraction of sectoral emissions in a single grid cell to sum of sectoral emissions.

12km BC Health Impact Analysis



Cost Function (number of premature deaths attributed to exposure to BC in continental US) = 12,600 (8,600 - 16,500) mortalities in 2007

12km BC Health Impact Analysis



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12km BC Health Impact Analysis



Effects of Grid Resolution on Estimates of Premature Deaths



Percent difference between all-cause mortality estimate at 12 km resolution and regridded to coarser resolutions (Punger and West, 2013)

Percent difference in mortality between regridded resolution and fine model resolution (Li et al., submitted)



Effects of Grid Resolution on Spatial Distribution of Premature Deaths

of Premature Deaths: 12km regridded - 36km



of Premature Deaths 12km regridded to 36km: 10,200 (7,000 - 13,400) 36km actual: 9,500 (6,500 - 12,500) -40

40

Effects of Grid Resolution on Spatial Distribution of Contributions

12km - 36km, 1 month simulation



of Premature Deaths 12km: 12,600 (8,600 - 16,500) 36km: 9,500 (6,500 - 12,500)

Sectoral Resolution Analysis





Conclusions

- Premature death estimates at coarser resolution lower than at 12km resolution.
- Coarser resolution adjoint simulations underestimate contributions from emissions in urban centers
 - Overestimate contributions from emissions along I-95 corridor
- Contributions from point sources have positive bias at coarser resolutions
- Benefits of source attribution of BC health impacts at 12km (over 36km) using adjoint sensitivities do not outweigh the extra computational cost of simulation.
 - Results for 12km sectoral breakdown of contributions within uncertainty range of 36km analysis