Issues for Health Metrics Related to Ambient Air Pollution

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Health Risk Assessment Methodology

Population \times \text{Baseline Rate of Health Outcome} \times \text{Change in Exposure} \times \text{Exposure-Response Function} = \text{Change in Number of Cases}

- **Number of Persons**: e.g., Deaths per 100,000 persons per unit time from past data
- **Baseline Rate of Health Outcome**: e.g., Modeled change in air pollution under policy scenarios
- **Change in Exposure**
- **Exposure-Response Function**: e.g., % increase in deaths per unit increase in air pollution – Epidemiology
Modeling Exposure

• Translates emission changes resulting from policy intervention to changes in ambient air pollution exposures for populations of interest

• Various approaches that range in complexity and robustness
  – Forward chemical transport modeling
  – Inverse (also called “adjoint”) chemical transport modeling
  – Reduced form models

• Spatial scales of analysis

• Temporal scales of analysis
Schematic for Global Atmospheric Model

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)
Chemical Transport Modeling – 2 Ways

**Forward Model (source-oriented)**

Sensitivity of all model concentrations to one model source

Modeling cost scales with # of sources and scenarios
Adjoint modeling for source-receptor analysis:

**Forward Model (source-oriented)**

Sensitivity of all model concentrations to one model source

- **Forward Perturbation at source region at $t_0$**
- Changes of concentration at $t_n$

**Adjoint Model (receptor-oriented)**

Sensitivity of model concentration in specific location to many model sources

- Concentration at the receptor at $t_n$
- adjoint
- area of possible origin at $t_0$

Can estimate source contributions to 1 receptor metrics with 1 adjoint run instead of 100,000 forward runs

Cost scales with # of sources
Issues of Spatial Scale

• Much air pollution health impact/benefit modeling has been done at the global or continental scales, using models that give answers on a coarse grid, e.g., 50 to 200 km\(^2\) grid boxes

• Some policy interventions are more local, e.g.,
  – Conversion of an urban vehicle fleet to cleaner technology
  – Village-level clean cooking fuel intervention

• These problems call for new and different modeling tools to get from emissions to exposures

• For ambient air, new tools are attempting to push down to 1 km\(^2\) and finer, but still a work in progress
Which Health Outcomes and Metrics?

1. Global Burden of Disease

Health outcomes

• PM2.5
  – Ischemic heart disease (MI and angina) – age specific
  – Stroke ("cerebrovascular disease") – age specific
  – COPD (Chronic Obstructive Pulmonary Disease)
  – Lung Cancer
  – Lower respiratory infection

• Ozone
  – COPD

Metrics

• Mortality – count of pollution-related deaths
• YLL – # of years of life lost due to mortality at various ages
• YLD – # of years lived with disability (i.e., years with disease)
• DALY – YLL plus (YLD x disability weight (ranging from 0 to 1))
• HALE – healthy life expectancy (years)
2. BenMAP US Health Impact Metrics

PM$_{2.5}$
- Long-term mortality – various causes of death
- Chronic bronchitis
- Acute Myocardial Infarction
- Hospital admissions – various cardiovascular and respiratory causes (e.g., congestive heart failure, COPD, asthma)
- Emergency department visits for asthma
- Acute bronchitis, work loss days, restricted activity days, lower respiratory symptoms (e.g., cough, shortness of breath, wheeze)

Ozone
- Short-term mortality – various causes
- Long-term respiratory mortality
- Hospital admission – various respiratory causes
- Emergency department visits for asthma
- Missed school days, restricted activity days
Health Outcome Challenges

• As noted, there is a high “entry barrier” for inclusion of new health outcomes. This derives from the historical attitudes about what constitutes sufficient biomedical evidence to, e.g., approve new drugs.

• As a result, list of outcomes we include in HIAs is surely too short.

• Over time, the list grows.

• Should we adopt biologic metrics such as oxidative potential of PM, as suggested in one paper that was provided?

• Can we differential the health impacts of different PM$_{2.5}$ components, e.g., BC?
Temporal Issues

- Depending on the health outcome, changes in health resulting from interventions may occur immediately or may roll out of many years.
- For cardiovascular effects, we think health benefits occur fairly quickly, i.e., same year.
- For chronic lung disease, benefits may occur for 3-5 years.
- Lung cancer benefits may occur for a decade or two.
- These “cessation lags” are often ignored.
Other Issues

• The increasing role of satellite remote sensing in air pollution health analyses
  – Plays key role in GBD study
  – Available tools continue to improve

• Most ambient air health burden studies to date don’t separate impacts by emission sources

• Most studies focus on mortality; increasing need for morbidity assessments for local policy making
Summary

• Modeling of exposure changes faces challenges related to technical complexity and spatial scales
  – Need simpler-to-use tools at finer scales
• Health outcome list varies by region of analysis, and underestimates total burden in all cases
• Evidence will continue to emerge on new health metrics and relative importance of different PM components