Integrated Air Quality Indicators

Application to Mobile Source Impacts on Emissions, Air Quality, Exposure and Health

Jorge Pachon, J. Mulholland, J. Sarnat, L. Darrow, Paige Tolbert, S. Balachandran, M. Maier and AG Russell

Georgia Institute of Technology and Emory University
Atlanta, Georgia

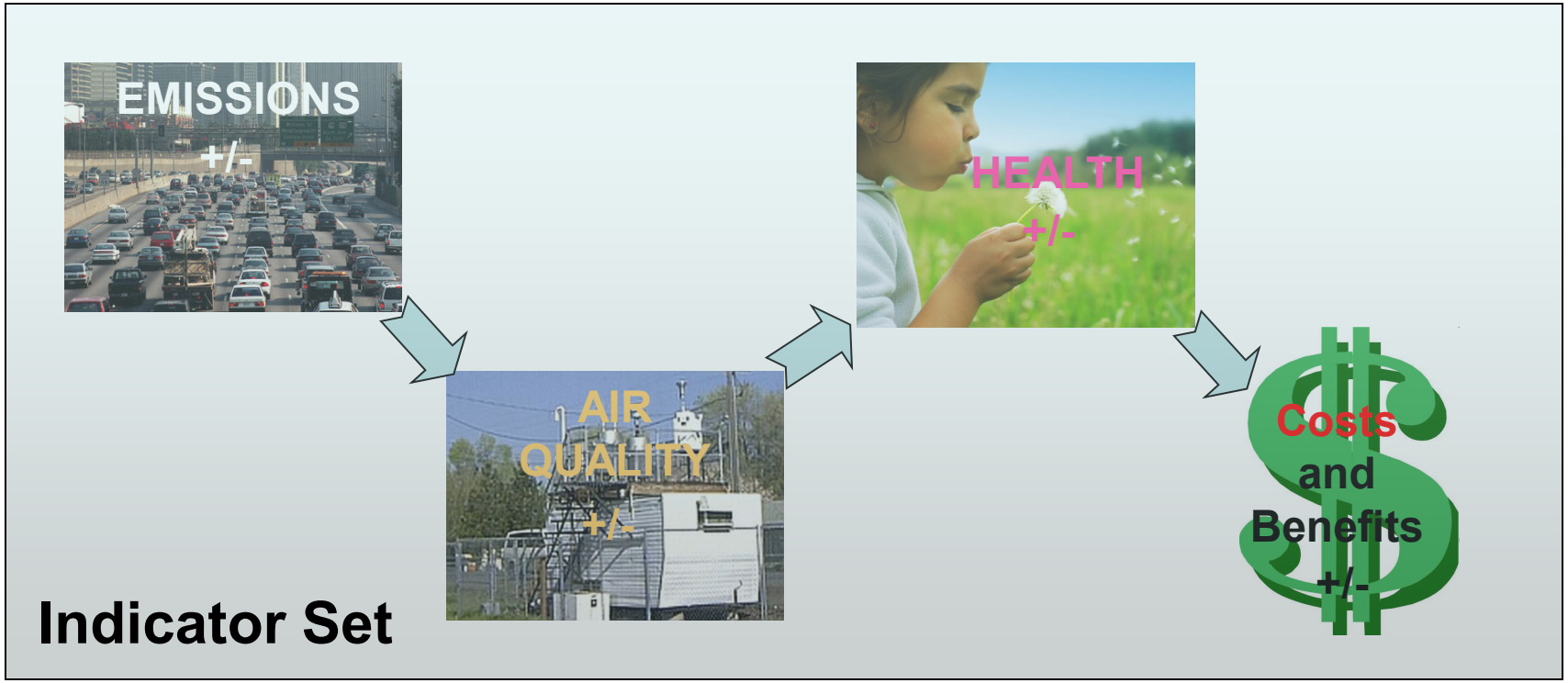
Georgia Institute of Technology

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R833626

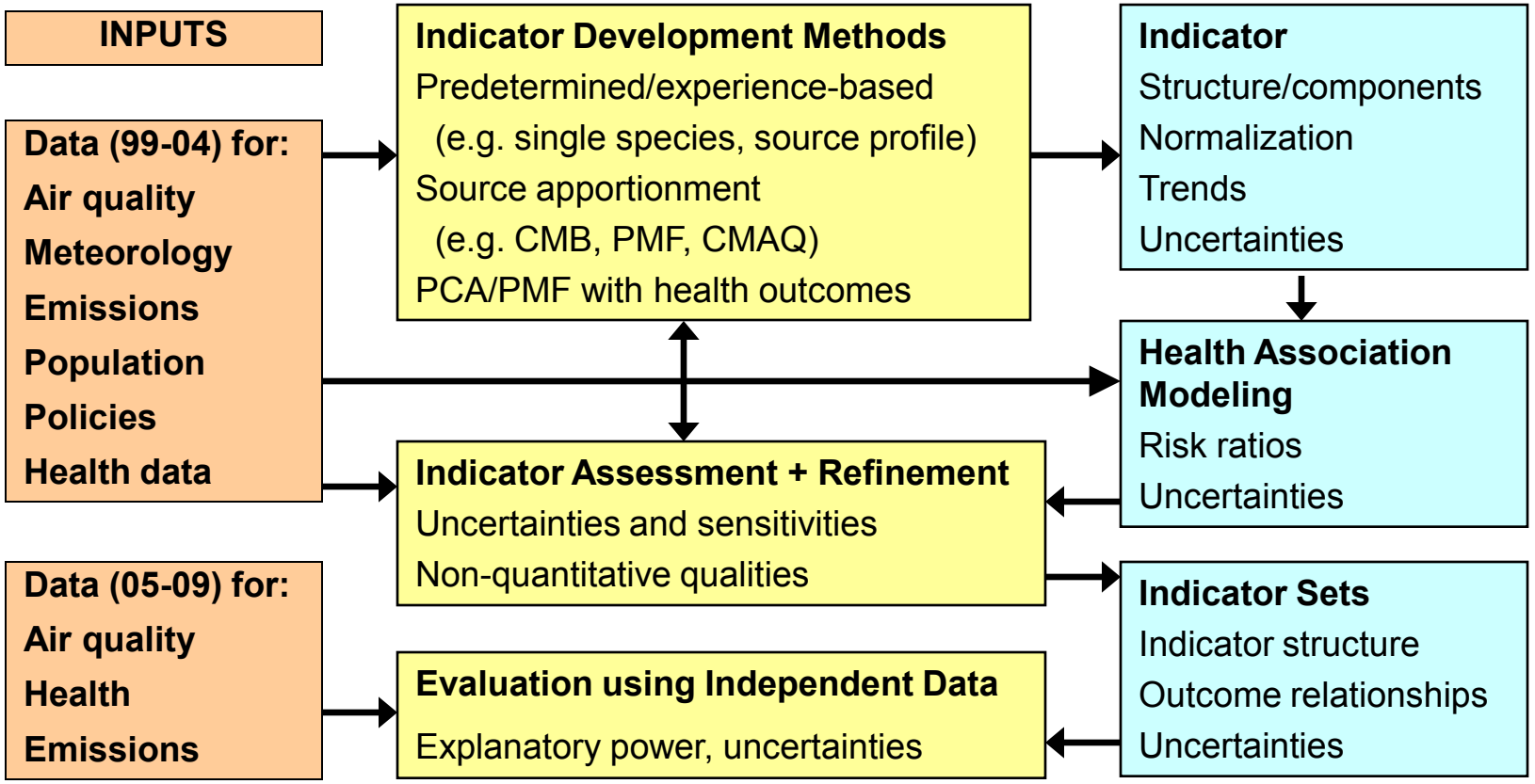
ROLLINS SCHOOL OF PUBLIC HEALTH
EMORY

Objective

- Develop and apply integrated multi-pollutant indicator sets linking estimated emissions changes to air quality, health impacts and cost savings
  - Provide uncertainties



Project overview



Emission-based Integrated Mobile Source Indicators (EB-IMSI)

- Integrated mobile source indicator
  - Captures emissions mixture
  - Combines estimates of emissions and observed concentrations

0.92±0.04 **0.84±0.03** **0.97±0.01**

$$EB-IMSI=\frac{\left(\frac{EC_{mob}}{EC_{tot}}\right)_{Emis} EC'+\left(\frac{NOx_{mob}}{NOx_{tot}}\right)_{Emis} NOx'+\left(\frac{CO_{mob}}{CO_{tot}}\right)_{Emis} CO'}{\left(\frac{EC_{mob}}{EC_{tot}}\right)_{Emis}+\left(\frac{NOx_{mob}}{NOx_{tot}}\right)_{Emis}+\left(\frac{CO_{mob}}{CO_{tot}}\right)_{Emis}}$$

EB-IMSI=0.34*EC+0.31*NOx+0.36*CO

$$EC'=\frac{EC}{\sigma_{EC}}$$

$$CO'=\frac{CO}{\sigma_{CO}}$$

$$NOx'=\frac{NOx}{\sigma_{NOx}}$$

Normalized concentrations

DIESEL (EB-IMSI-DV)

0.90±0.04 **0.35±0.02**

$$EB-IMSI_{DV}=\frac{\left(\frac{EC_{DV}}{EC_{tot}}\right)_{Emis} EC'+\left(\frac{NOx_{DV}}{NOx_{tot}}\right)_{Emis} NOx''}{\left(\frac{EC_{DV}}{EC_{tot}}\right)_{Emis}+\left(\frac{NOx_{DV}}{NOx_{tot}}\right)_{Emis}}$$

EB-IMSI-DV=0.3*NOx+0.7*EC

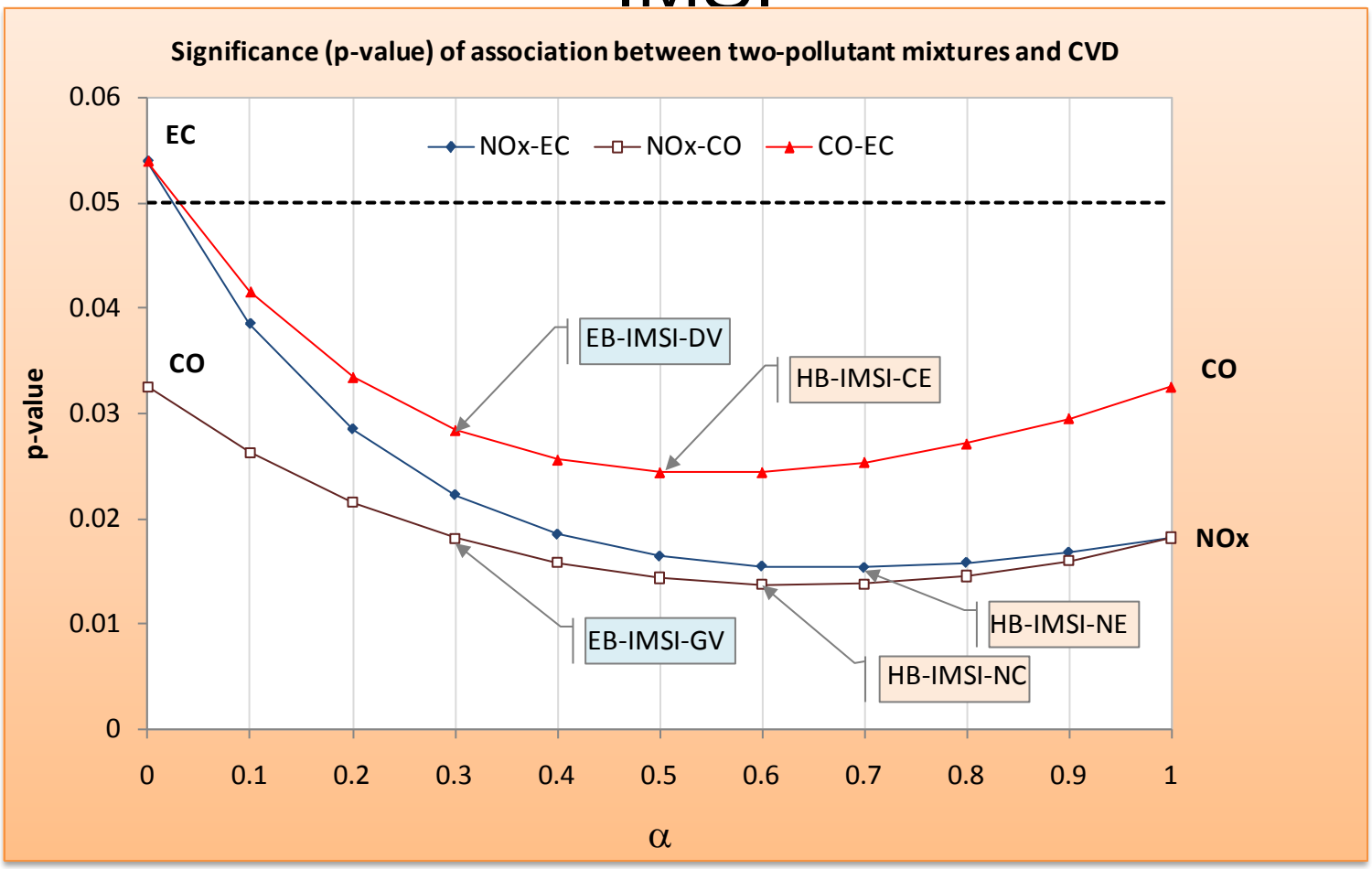
Health Analysis, Poisson regression

$$\mathrm{Log}[\mathrm{E}(Y)] = \alpha + \beta\, pollutant + \sum_{\mathrm{k}} \lambda_{\mathrm{k}}\, day\text{-}of\text{-}week_{\mathrm{k}}$$
$$+ \sum_{\mathrm{m}} \nu_{\mathrm{m}}\, hospital_{\mathrm{m}} + \sum_{\mathrm{p}} \zeta_{\mathrm{p}}\, holiday_{\mathrm{p}}\, \mathrm{g}(\gamma_1, \ldots, \gamma_{\mathrm{N}};\, time)$$
$$+ \mathrm{g}(\delta_1, \ldots, \delta_{\mathrm{N}};\, temperature) + \mathrm{g}(\eta_1, \ldots, \eta_{\mathrm{N}};\, dewpoint)$$

Indicator	IQR	RR per IQR	95% CI	p-value
NOx-1h	0.1 ppm	1.008	1.001 – 1.015	0.018
EB-IMSI-GV	0.8	1.009	1.002 – 1.017	0.018
EB-IMSI-DV	0.7	1.010	1.001 – 1.018	0.022
EB-IMSI	2.3	1.007	1.001 – 1.014	0.029
CO-1h	0.9 ppm	1.007	1.001 – 1.014	0.033
EC	1.0 $\mu g/m^3$	1.008	1.000 – 1.017	0.054

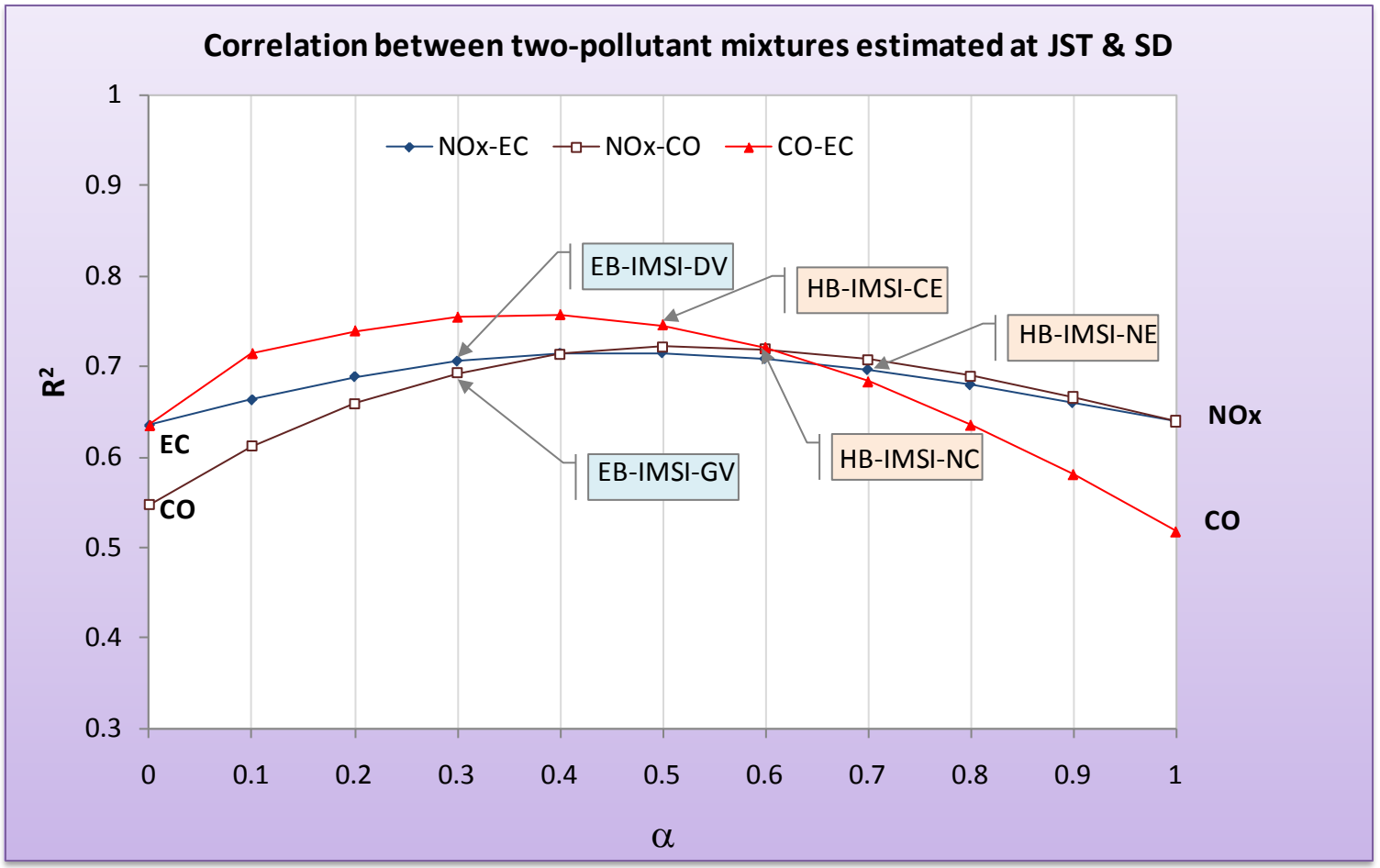
- Within single species, NOx is the most strongly associated with CVD, followed by CO and EC.
- When the three pollutants are combined in the EB-IMSI, the strength of association is greater than either EC or CO separately

Associations with CVD and Health-based IMSI



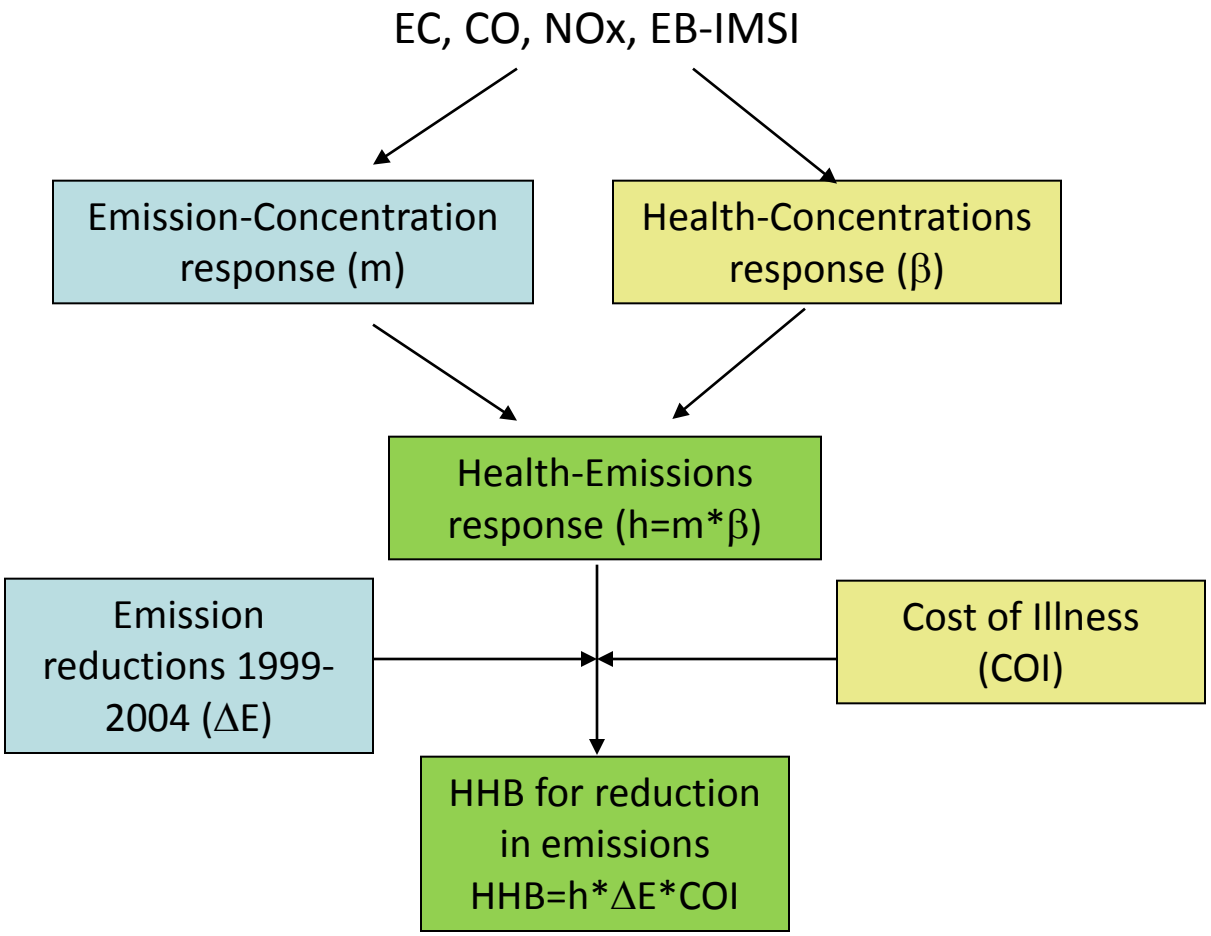
- Health-based Indicators are defined at the point where the association with CVD is strongest for every two-pollutant mixture.

Spatial variability analysis



- The correlation between two-pollutant mixtures estimated at JST and the corresponding mixture at SD is stronger than singles species, suggesting better spatial representativeness.
- A stronger spatial representativeness may explain stronger associations with health.

Estimation of Human Health Benefits (HHB)



Estimate of Human Health Benefit In Atlanta: CVD Visits

	CO	NOx	EC	EB-IMSI	EB-IMSI-GV	EB-IMSI-DV
CVD visits avoided/yr	**16 (5-27)**	**9 (4-14)**	**7 (1-13)**	**14 (5-23)**	**13 (4-22)**	**11 (4-18)**
Annual savings in costs (million $)	0.30 (0.10-0.50)	0.16 (0.07-0.25)	0.13 (0.02-0.24)	0.25 (0.09-41)	0.24 (0.08-0.40)	0.20 (0.08-0.32)
Savings per ton of emission ($/ton)	28 (15-41)	112 (46-168)	17,600 (7,000-27,000)	21 (11-31)	21 (11-31)	240 (100-380)
Average emission reduction (tons/yr)	10,690	1,450	7.3	12,150	11,300	830

Summary

- Developed integrated indicator sets for mobile source impacts
  - Integrated
    - Multi-pollutant
      - Can capture mixture
    - Across “accountability” chain for assessing policies
      - Emissions➔Air quality➔Health➔Costs/Benefits
    - Uncertainties
  - Uses readily available information
- Integrated indicators more spatially consistent
  - Slightly stronger (not greater) association with CVD outcome
- Can provide easily used approach to assess air quality impacts of policy choices
  - Integrate global change responses

Relative uncertainties (Unc./Indicator)

	Range
Emissions	0.03-0.18
Conc-emissions	0.10-0.33
Ambient	0.14-0.88
HHB	0.47-0.59
Receptor models	0.26-1.48

- Uncertainties from mobile source emission estimates are the lowest and uncertainties from mobile source impacts from receptor models are the highest.
- Estimates of health benefits as a result of reduction in mobile emissions were more uncertain.

Indicators and Indicator Set Example: NOx

INDICATORS

Indicator	Associated Outcomes	Attributes
NOx emissions	Long-term emissions reflect effectiveness of policies	NOx mobile source emissions estimated with MOVES 2010a.
NOx ambient	Indicator of mobile source impact on air quality	NOx ambient measured by chemiluminescence every hour.
Health impact	Indicator of cardiovascular health associated with NOx ambient concentrations	NOx ambient concentrations obtained at a central monitor.

INDICATOR SET