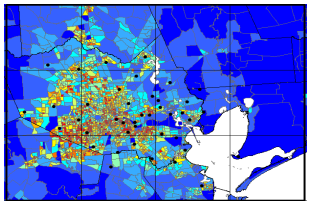
Influence of Air Quality Model Resolution on Uncertainty Associated with Health Impacts

Tammy M. Thompson & Noelle E. Selin
Massachusetts Institute of Technology
Joint Program on the Science and Policy of Global Change

Introduction/Motivation

- Non-Attainment of National Ambient Air Quality Standards (NAAQS) for criteria pollutants requires Attainment Demonstrations to be conducted by States
- Air Quality Modeling conducted in support of attainment demonstrations does not include model uncertainty
- EPA Guidance requires modeling at fine scale resolution of at least 12km, with 4km recommended for regulatory purposes
- Attainment is based only on concentrations at monitor locations, does not take population distribution into account

Monitor Locations/Population Density 2km Domain, 36km Grid Cells



So we ask:

"Are attainment demonstrations being done in the most effective way, keeping in mind that protection of human health is the ultimate objective?"

Clean Air Act Cost/Benefits Analysis

- Section 812 of CAA requires EPA to do a Cost/Benefit of the act

- There are uncertainties associated with each step. Most are unknown
- Uncertainties associated with concentration response functions (health impacts) however, are fairly well known

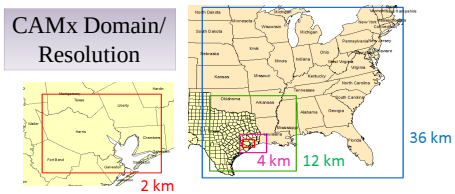
Air Quality Modeling

Limitations of Regional Air Quality Modeling

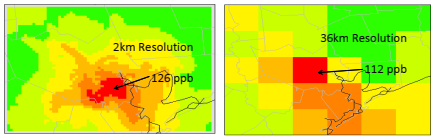
- Limited ability to run uncertainty analyses because of time/memory requirements of fine scale modeling
- Extensive input data requirements
- Low level emissions are immediately and homogeneously dispersed throughout the grid cell they are emitted in
  - Coarse modeling can under-predict daily maximum values
  - Coarse modeling can over-predict nighttime values (daily minimum values)
  - Model often misses "titration effect" that can occur near large NOx sources

2006 "Base Case"

CAMx Domain/ Resolution



Coarse Resolution "Dilutes" Max Ozone September 1, 2006 1 Hour Max

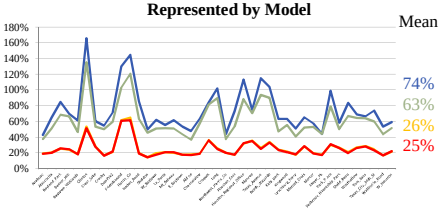


How well do model results from each resolution represent ozone concentrations measured at monitor stations?

Mean Normalized Gross Error

$$MNGE = \frac{1}{N}\sum_{1}^{N}\left(\frac{|Model - Obs|}{Obs}\right) * 100\ \%$$

8-hr Daily Max Measured Values Not Well Represented by Model



Houston/Galveston/Brazoria Area Monitors

36k error 12k error 4k error 2k error

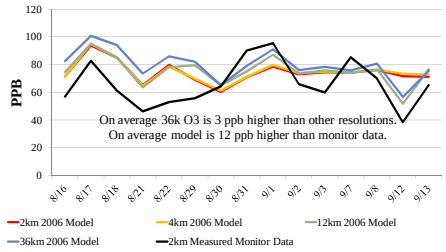
MNGE of Model vs Model

MNGE of "coarse" resolution modeling (36 km, 12 km, and 4 km) vs. 2 km "fine" resolution modeling are15%, 9% and 1% respectively, showing:

- **Model results are consistent between resolutions**
- **Model results more similar to each other than to measured values.**

Population Weighted 8-Hour Ozone Concentrations

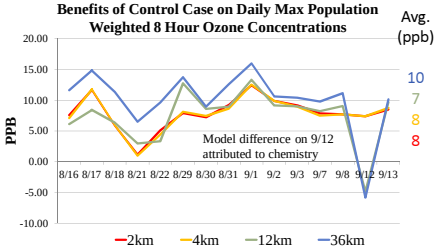
Population Weighted 8-Hour Ozone Represented Slightly Better by Model



2018 "Control Case" Results

On average across the episode, the 2018 Attainment Demonstration "Control Case" reduces the Population Weighted Ozone Concentration by 8 ppb for the "fine" 2 km resolution.

Benefits of Control Case on Daily Max Population Weighted 8 Hour Ozone Concentrations



Estimated benefits of 2018 Control Case to human health are calculated by applying average change in ppb (shown above) to concentration response functions for ozone

- When modeled at 2km, 4km, and 12km resolution, 2018 control case estimates a reduction of **5 deaths** (per ozone month) with 95% confidence interval of **2-7**
- When modeled at 36km resolution, 2018 control case estimates a reduction of **7 deaths** (per ozone month) with 95% confidence interval of **2-9**
- Basecase ozone related mortality is: 44 (15,58) per ozone month (out of ~6 million people)

Full Human Health Impacts of Control Case

Mean with 95% Confidence Interval	Change in Mortality	Respiratory Hospital Admissions Adults >65 yrs	Respiratory Symptom Day	Minor Restricted Activity Day	Asthma Attack	Bronchodilator usage
Values Calculated Using Population Weighted Concentrations as Measured by Air Quality Monitors in 2006						
06 Monitor Data	44 (15,58)	207 (-83,497)	546442 (94385,1043208)	190427 (72859,314618)	71037 (5464,137438)	1208796 (-430530,2649416)
Change (Decrease) in Metrics between the 2006 Modeled Basecase and the 2018 Modeled Control Case						
Model 2k	5 (2,7)	25 (-10,60)	65466 (11308,124980)	22814 (8729,37692)	8511 (655,16466)	144818 (-51579,317409)
Model 4k	5 (2,7)	24 (-10,59)	64601 (11158,123330)	22513 (8613,37195)	8398 (646,16248)	142906 (-50898,313218)
Model 12k	5 (2,7)	23 (-9,56)	61302 (10589,117031)	21363 (8174,35295)	7969 (613,15418)	135607 (-48299,297222)
Model 36k	7 (2,9)	32 (-13,76)	83552 (14432,159508)	29117 (11140,48106)	10862 (836,21015)	184827 (-65829,405101)

Discussion

Given the cost/benefit requirements of the Clean Air Act and the uncertainty associated with human health impacts, it would appear:

- Population-Weighted Concentration is an acceptable metric for evaluating impacts of ozone control scenarios
- Uncertainty analyses on model results could be conducted at 36km resolution
- Perhaps a new way of conducting attainment demonstrations?

Ongoing Work

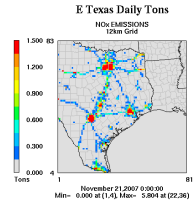
U.S. REP

Models Economic Sectors in the U.S. and the response to policy scenarios

Link economic sector with SCC code, and economic region with state FIPS to create a control input file

SMOKE

Emissions Preprocessing (Controls, Speciation, and Spatial and Temporal Allocation)

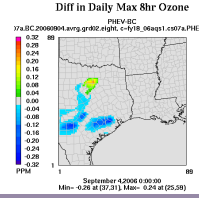


Input emissions inventories into air quality model to compare policy scenarios with BAU "Basecase" Air Quality

CAMx

3-D Photochemical Air Quality Modeling Evalutes the impacts of economic scenarios on criteria pollutants

Air Quality results from CAMx, in the form of estimated human health impacts, are fed back into U.S.Rep



Acknowledgements

The research described has been supported by the U.S. Environmental Protection Agency's STAR program through grant R834279 and by the MIT Joint Program on the Science and Policy of Global Change. It has not been subjected to any EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.