Using CAMx/HDDM to Estimate Ozone Response to US Anthropogenic NOx and VOC Reductions

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BACKGROUND

- EPA is assessing health risk for 16 cities over 2006-2010 at alternative ozone standards (EPA, 2012)
  - Health risk models use hourly ozone monitor data
  - Hourly data are rolled back to just meet alternative standards
- Past assessments applied simple linear and quadratic rollback techniques uniformly to all sites in each city
- Model-based rollback using HDDM is a better approach
  - Allows site-specific rollback and realistic non-linear ozone responses
  - Eliminates running multitude of "brute-force" emission scenarios
  - Subject to usual model uncertainty and higher-order truncation errors

- **OBJECTIVE:** Run CAMx with HDDM for 2006 at high resolution over the entire US
  - Evaluate against "brute force" 0%/100% US anthropogenic emissions
  - Evaluate against quadratic rollback
  - Develop efficient methods to estimate 1-hour ozone time series at any location

SUMMARY

We develop and evaluate a method for estimating annual time-series of hourly ozone anywhere in the US at any US anthropogenic emission level between 100% and zero. A single CAMx photochemical model run with HDDM measures first and second-order ozone sensitivity to emissions at 50% across-the-board NOx and VOC reductions from a 2006 baseline. Accuracy of the HDDM ozone projections is evaluated by comparison with brute force simulations with 100% and 0% US anthropogenic emissions. A post-processing macro efficiently generates ozone time series at all CASTNET sites and AQS monitoring sites in 23 cities for any NOx or VOC emission level. Ozone responses are complex, and HDDM can account for spatio-temporal influences from meteorology, emissions, and chemistry. Relative to quadratic rollback, HDDM estimates more realistic ozone response throughout the entire site-specific frequency distribution and lessens exposure reductions.

APPROACH AND RESULTS

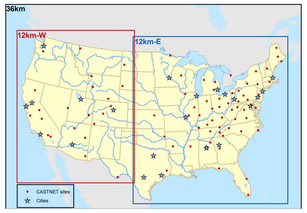
APPROACH

- High-order Decoupled Direct Method (HDDM) calculates 1st and 2nd order sensitivities (derivatives) of ozone to changes in NOx and VOC

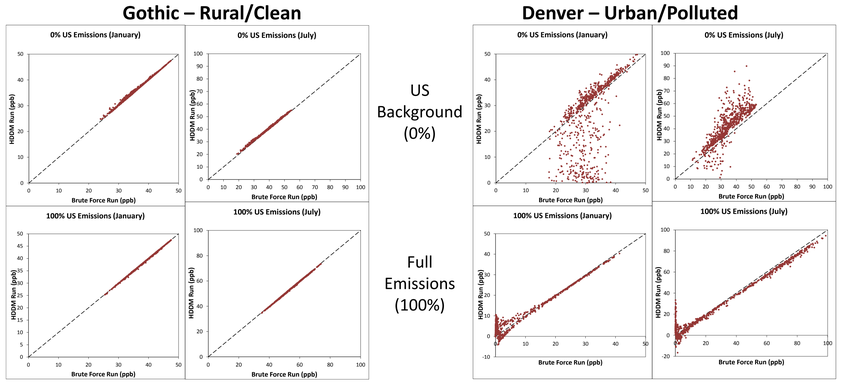
$$\Delta O_3\ (ppb) = X \cdot S^1_{NOx} + Y \cdot S^1_{VOC} + (X^2 \cdot S^2_{NOx}/2) + (Y^2 \cdot S^2_{VOC}/2) + (X \cdot Y \cdot S^2_{NOxVOC}/2)$$

$$S^1_{NOx} = \partial O_3/\partial NO_x$$
$$S^1_{VOC} = \partial O_3/\partial VOC$$
$$S^2_{NOx} = \partial^2 O_3/\partial NO_x^2$$
$$S^2_{VOC} = \partial^2 O_3/\partial VOC^2$$
$$S^2_{NOxVOC} = \partial^2 O_3/\partial NO_x \cdot \partial VOC$$

- Comprehensive Air quality Model with extensions (CAMx v5.40)
  - 2006 12-km US-wide CAMx modeling (Emery et al., 2012)
  - AQMEII US emissions/meteorological dataset (Rao et al., 2010)
  - 50% across-the-board US anthropogenic NOx and VOC emissions
  - Hourly HDDM ozone sensitivity to US-wide NOx, VOC and NOx+VOC
  - Macro tool evaluates emissions scenarios at 79 rural CASTNET sites, 361 urban AQS sites in 23 US cities



COMPARISON AGAINST BRUTE-FORCE

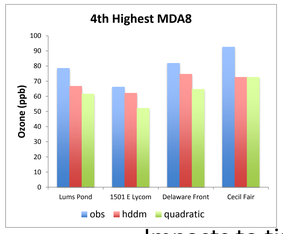


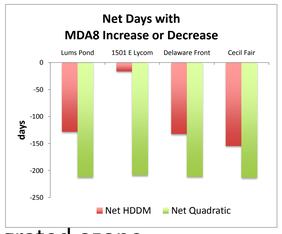
COMPARISON AGAINST QUADRATIC ROLLBACK

Example: 4 Sites in Philadelphia

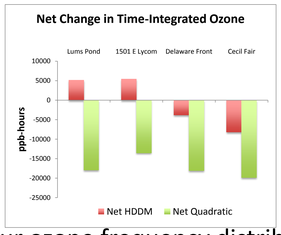
DV=70 ppb, 48% NOx & VOC Reduction

Impacts to max daily 8-hour average ozone (MDA8)

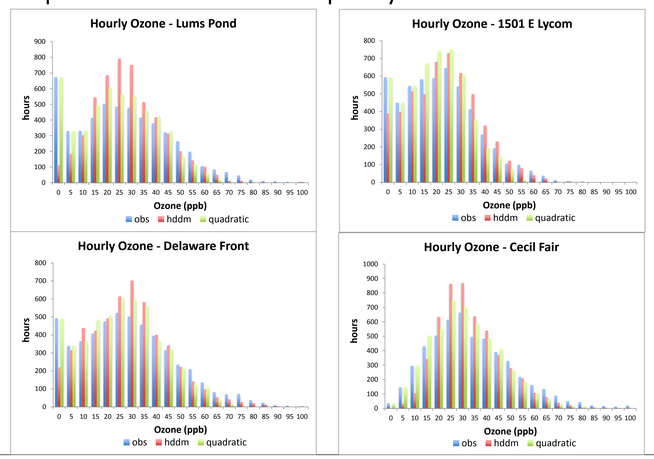




Impacts to time-integrated ozone



Impacts to 1-hour ozone frequency distributions at 4 sites



DISCUSSION

- HDDM vs. Brute-Force
  - Compares well at rural sites with little anthro contribution
  - Good agreement at urban sites for 100% (base) emissions
  - Poor agreement at urban sites for 0% (background) emissions
  - For now, focus on 50-100% of base emissions (upper end)
- HDDM vs. Quadratic Rollback
  - HDDM estimates more realistic response over entire ozone distribution
  - HDDM usually (not always) leads to smaller reductions of high ozone
  - HDDM shifts low ozone upward toward simulated background
  - Net HDDM ozone impact lessens exposure reduction
  - Intra-urban differences are important and unique

FUTURE DIRECTIONS

- New HDDM run near background to improve method
- Address policy-relevant questions (e.g., ozone distributions with minimal emissions, reductions necessary to meet alternative standards)
- Compare to other approaches

ACKOWLEDGEMENTS

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