Air Pollution Social Costs Estimated With Chemical Transport Models

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Air Pollution Often Dominates

Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security

Science (2012)

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Black carbon mitigation may have some benefits as a short-lived climate forcer

…but definitely has large benefits now for health (25x as big)

	CH_4	BC Tech
Valuation		
Climate, billions $US	331 ± 118	142 (+71/–106)
($US per metric ton CH_4)	(2381 ± 850)	
Crops, billions $US	4.2 ± 1.2	3.6 ± 2.6
($US per metric ton CH_4)	(29 ± 8)	
Health, billions $US	148 ± 99	3717 (+3236/–2563)
($US per metric ton CH_4)	(1080 ± 721)	

Social Cost Metrics

$$\text{Social Cost} \simeq \begin{pmatrix} \Delta\text{Mortality Rate} \\ \text{by } \Delta\text{PM}_{2.5} \end{pmatrix} \times (\text{Exposed Population}) \times (\text{Value of a Statistical Life})$$

- Requires
  - AQ model (emissions → concentrations)
  - epidemiology “concentration-response” (mortality)
  - exposure (population density, spatial resolution)
  - value of a statistical life
- Frequently reported as $ per ton emissions
- “Marginal emissions” ($/ton)
  - assumes linear response; appropriate for small Δ

Prior Work

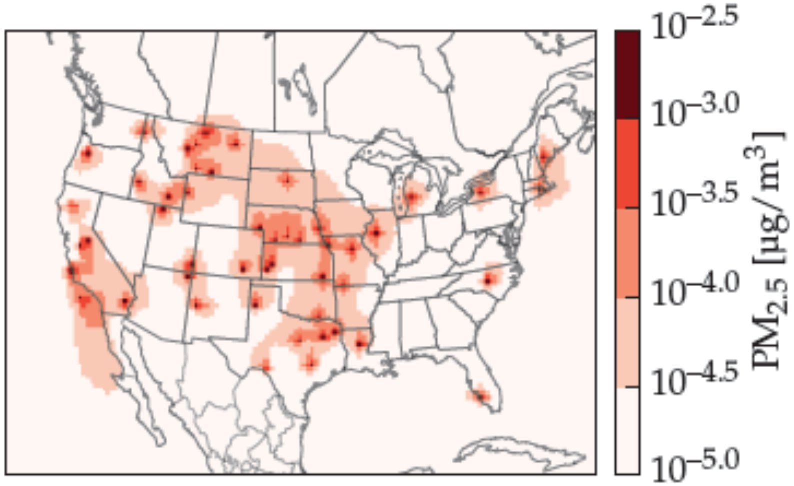
- Dispersion model based estimates
  - ***lack rigorous treatment of secondary (i.e. not directly emitted) PM2.5 formation***
  - not recommended for long distance transport
  - e.g. CRDM → APEEP, COBRA
- Chemical transport models (CTMs)
  - ***computationally intensive***
  - one-off simulations of specific policies (e.g CSAPR)
  - Response Surface Model (RSM), papers by Fann
  - simulations tend to aggregate emissions nationally, regionally, and/or by sector
- Reduced-form models inherit problems of AQ model

Goal

- Provide marginal social costs ($/ton) that are
  - simple, easy-to-use
  - computationally efficient
  - ***<u>based on state-of-science CTM</u>***
  - ***<u>approx county-scale spatial resolution</u>***
  - seasonal variability
- Brute force: ~9,000 CPU-years

- Resulting tool is EASIUR
  - (Estimating Air quality Social Impacts Using Regression)

Partial Solution: "Tagged" Simulations



PSAT simulation with 50 tags for July

(6.6 kg EC/day were added at each location)

CAMx Particulate Source Apportionment Technology (PSAT)

- tracks the contributions of multiple emission sources separately on $PM_{2.5}$ concentrations in all receptor locations.

  (Wagstrom et al, 2008; Koo et al, 2009)

- reduces computational costs substantially by a factor of ten, creating a large dataset for this study.

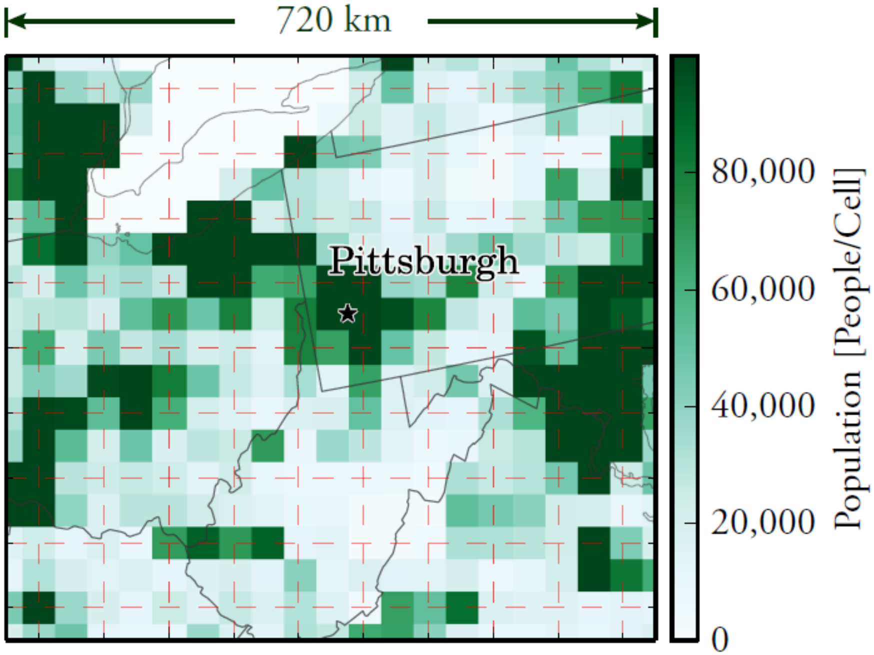
Provides large data set of locations

… still not every county in US

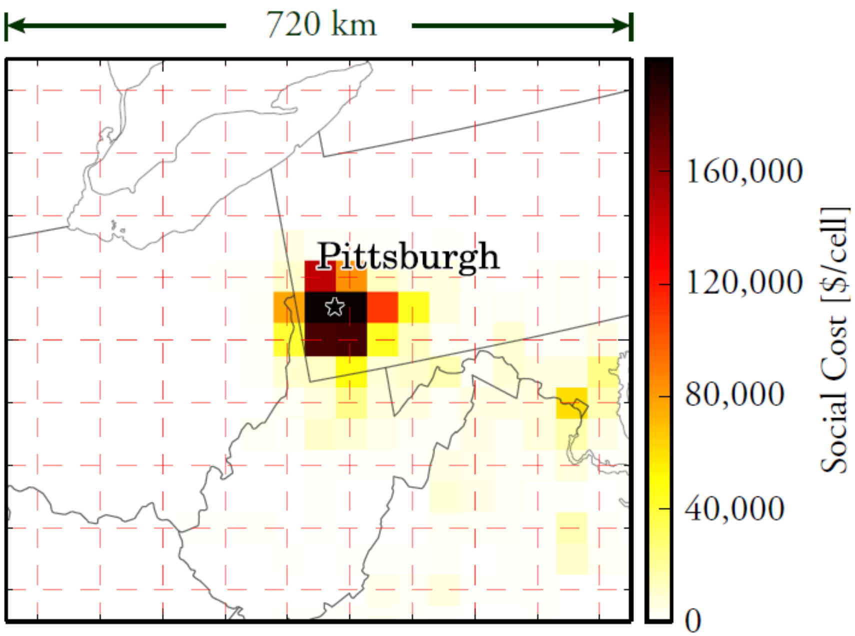
EASIUR

Estimating Air pollution Social Impacts Using Regression (EASIUR)

$$\text{Social Cost} \simeq \begin{pmatrix}\Delta\text{Mortality Rate}\\ \text{by } \Delta PM_{2.5}\end{pmatrix} \times \boxed{(\text{Exposed Population})} \times (\text{VSL})$$



Population around Pittsburgh



Social Cost of Pittsburgh Elemental Carbon

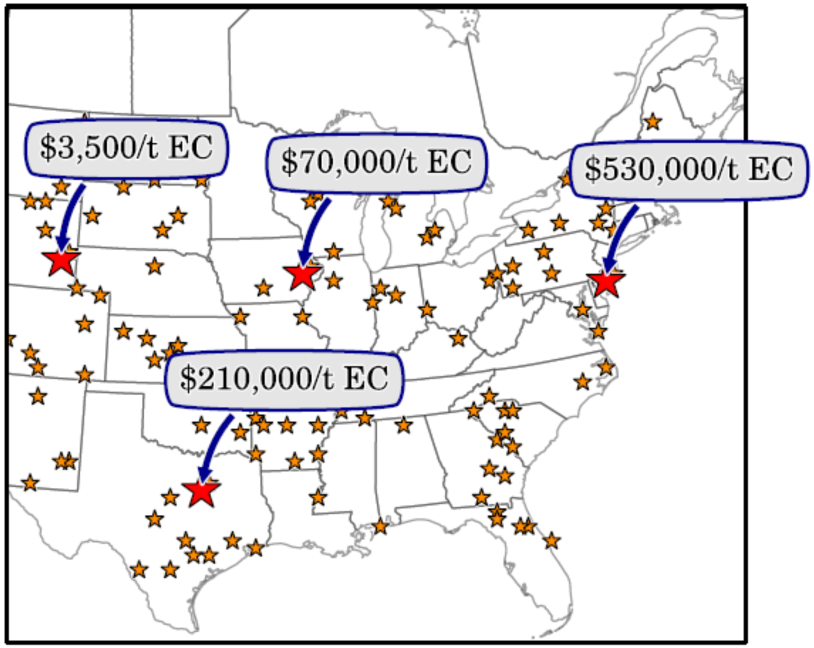
3 t EC/day emitted in Pittsburgh

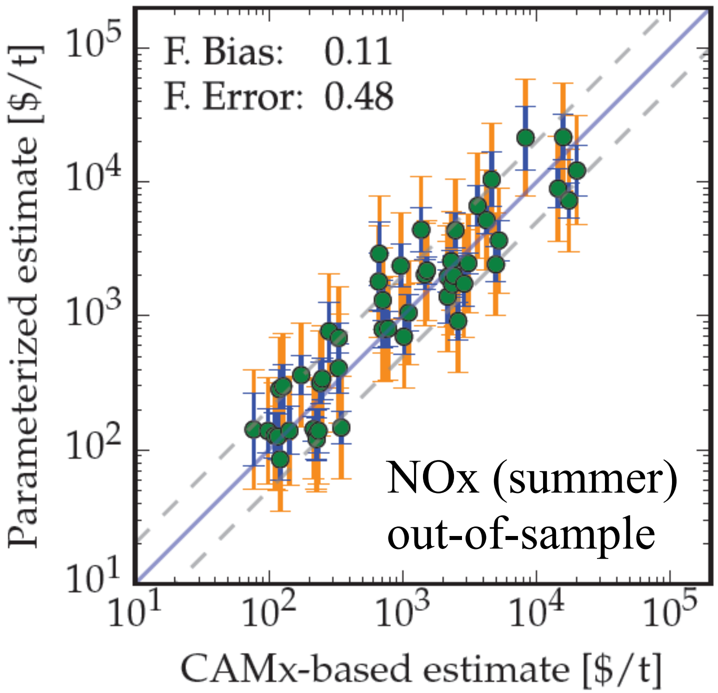
Research Design

Our goal is to derive:

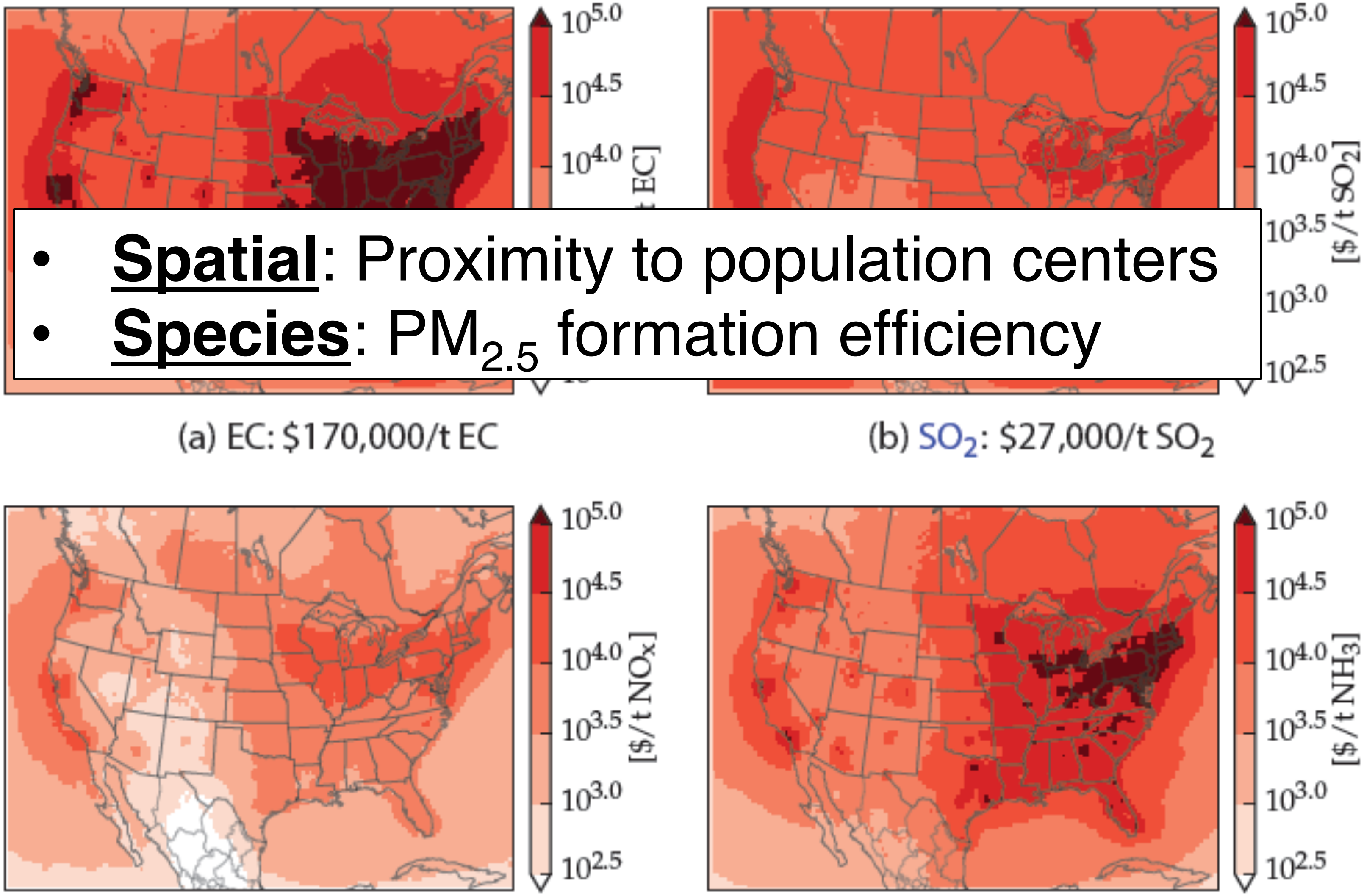
Per-tonne Social Cost [$/t]	= *f* (Population, Atmospheric Variables)
Intake Fraction [ppm]	= *g* (Population, Atmospheric Variables)

3. Calculate per-tonne social costs and intake fractions for the 100 locations.





EASIUR Results (per tonne)



- **Spatial**: Proximity to population centers
- **Species**: $PM_{2.5}$ formation efficiency

(a) EC: \$170,000/t EC

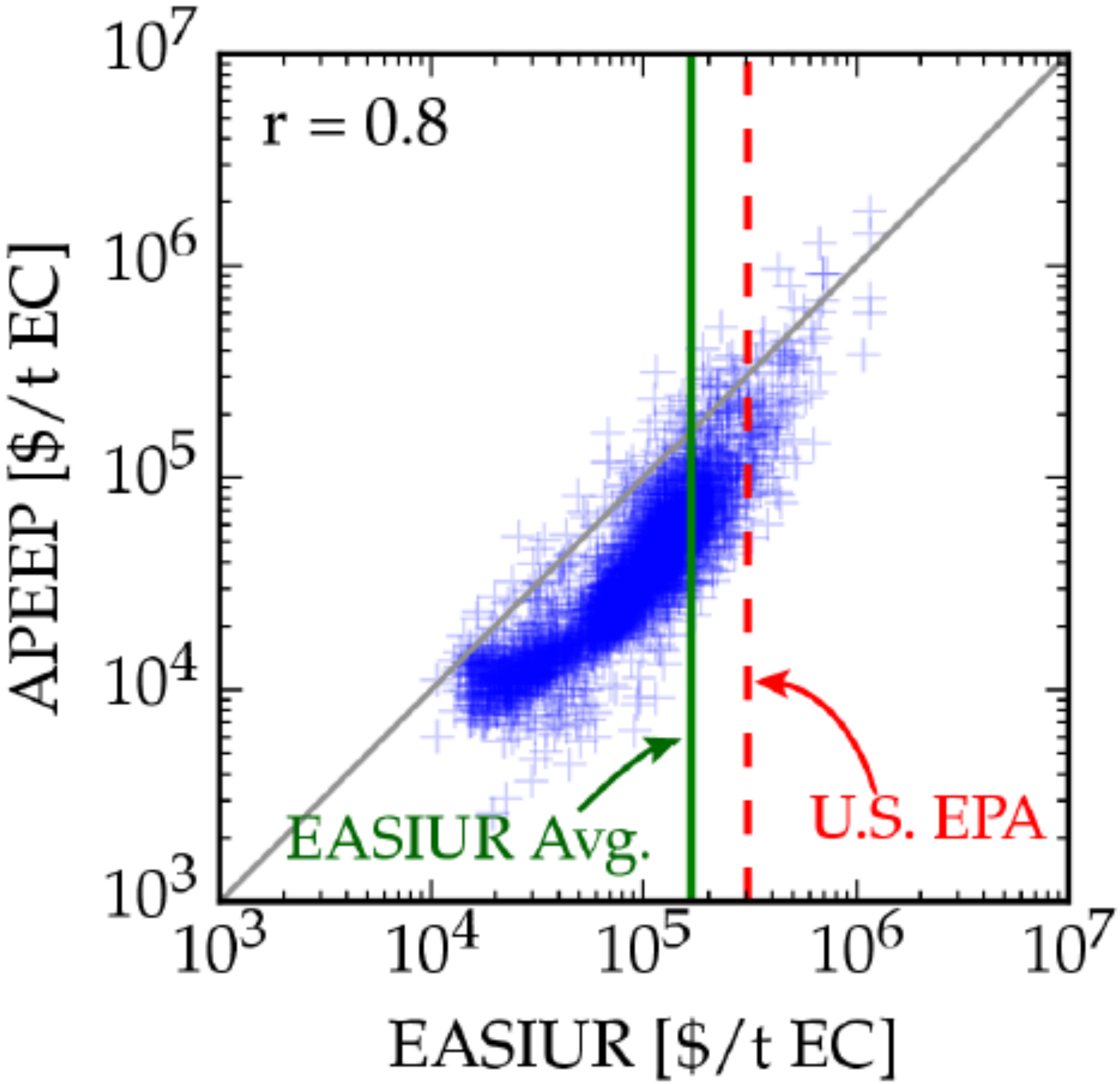
(b) SO_2: \$27,000/t SO_2

(c) NO_x: \$9,700/t NO_x

(d) NH_3: \$46,000/t NH_3

EASIUR vs APEEP: Spatial Correlations?

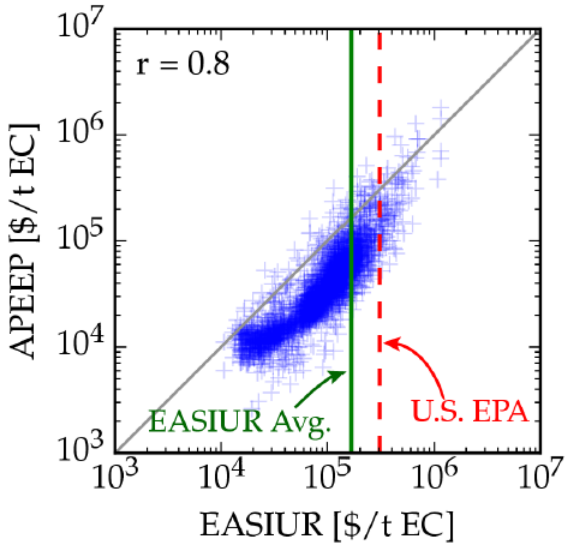
EC
inert
r = 0.8

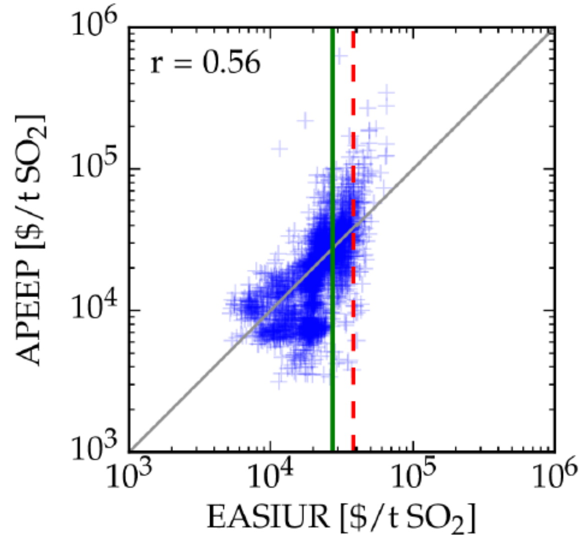


each + represents one county

EASIUR vs APEEP: Spatial Correlations?

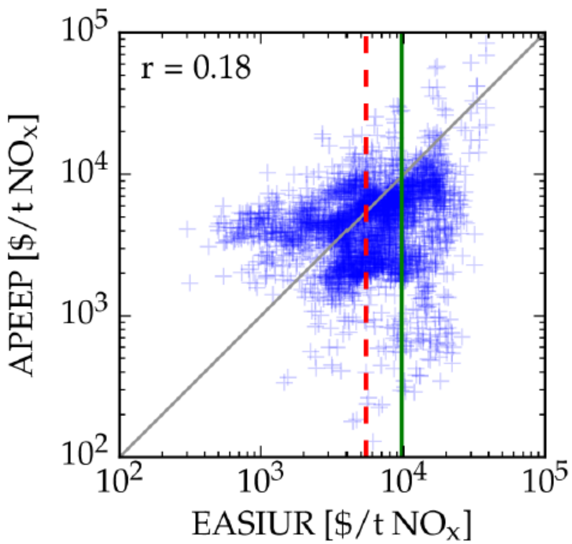
<u>EC</u>
inert
r = 0.8

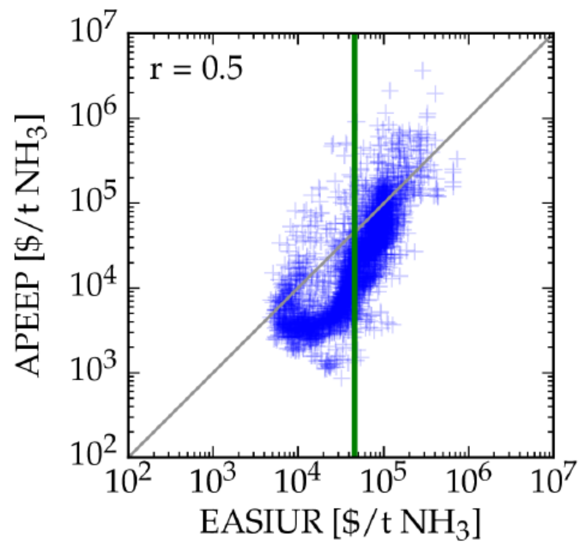




<u>SO2</u>
chem
r = 0.56

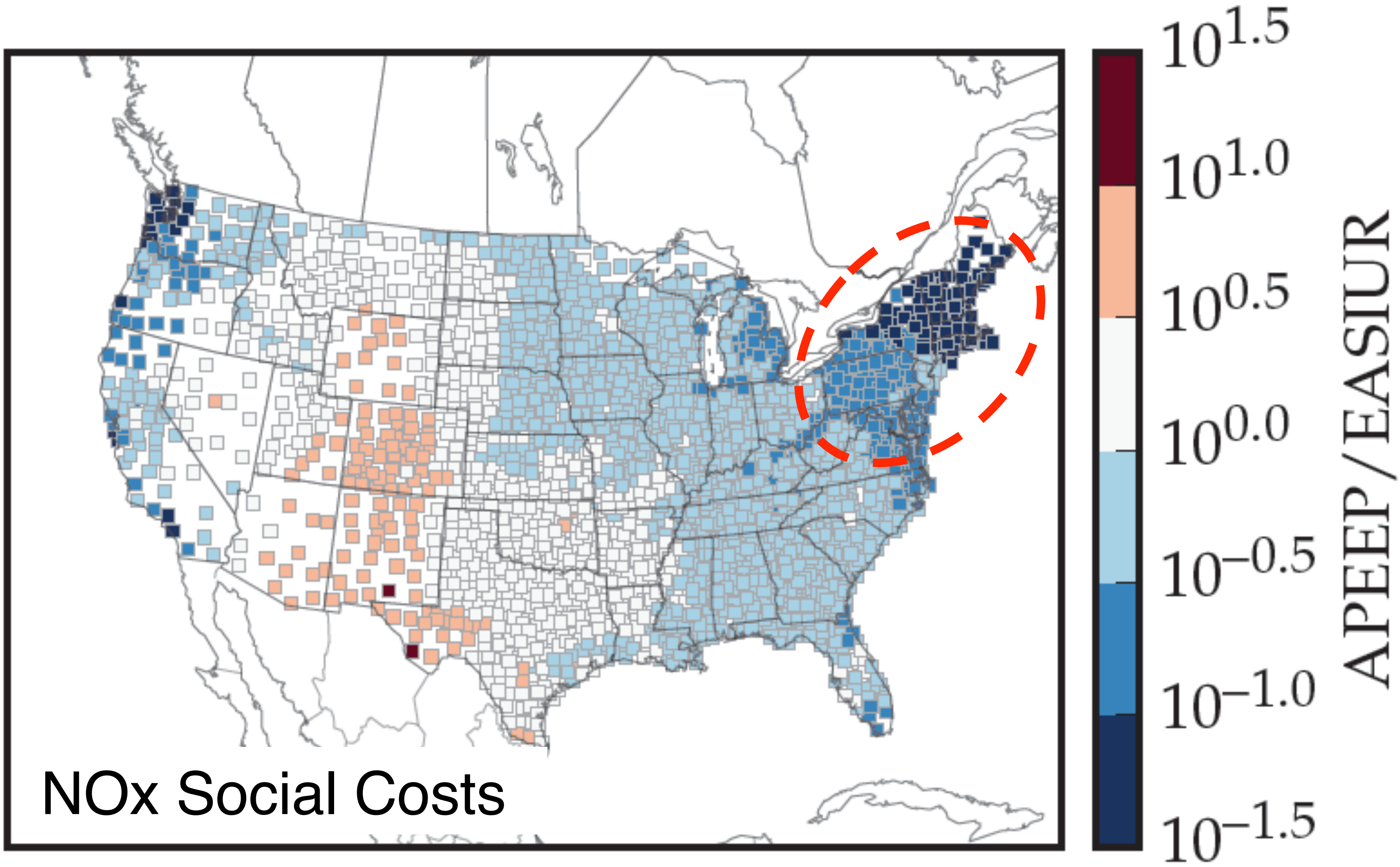
<u>NOx</u>
chem / thermo
r = 0.18





<u>NH3</u>
thermo
r = 0.5

EASIUR vs APEEP Comparison



EASIUR: Contribution

- CTMs: slow, for air quality experts
- Previous tools either
  - not based on rigorous model
  - lacked spatial resolution
- Built “EASIUR” to address deficiencies
- Discrepancies/uncertainties between tools
  - factor of ~2, nationally averaged, most species
  - factor of up to 10, difficult species over some regions
  - bias with APEEP seems to be systematic for species with complex atmospheric behaviors
- Extensions: organic $PM_{2.5}$