Using NASA Earth Data to Evaluate Impacts of Air Quality on Respiratory Health

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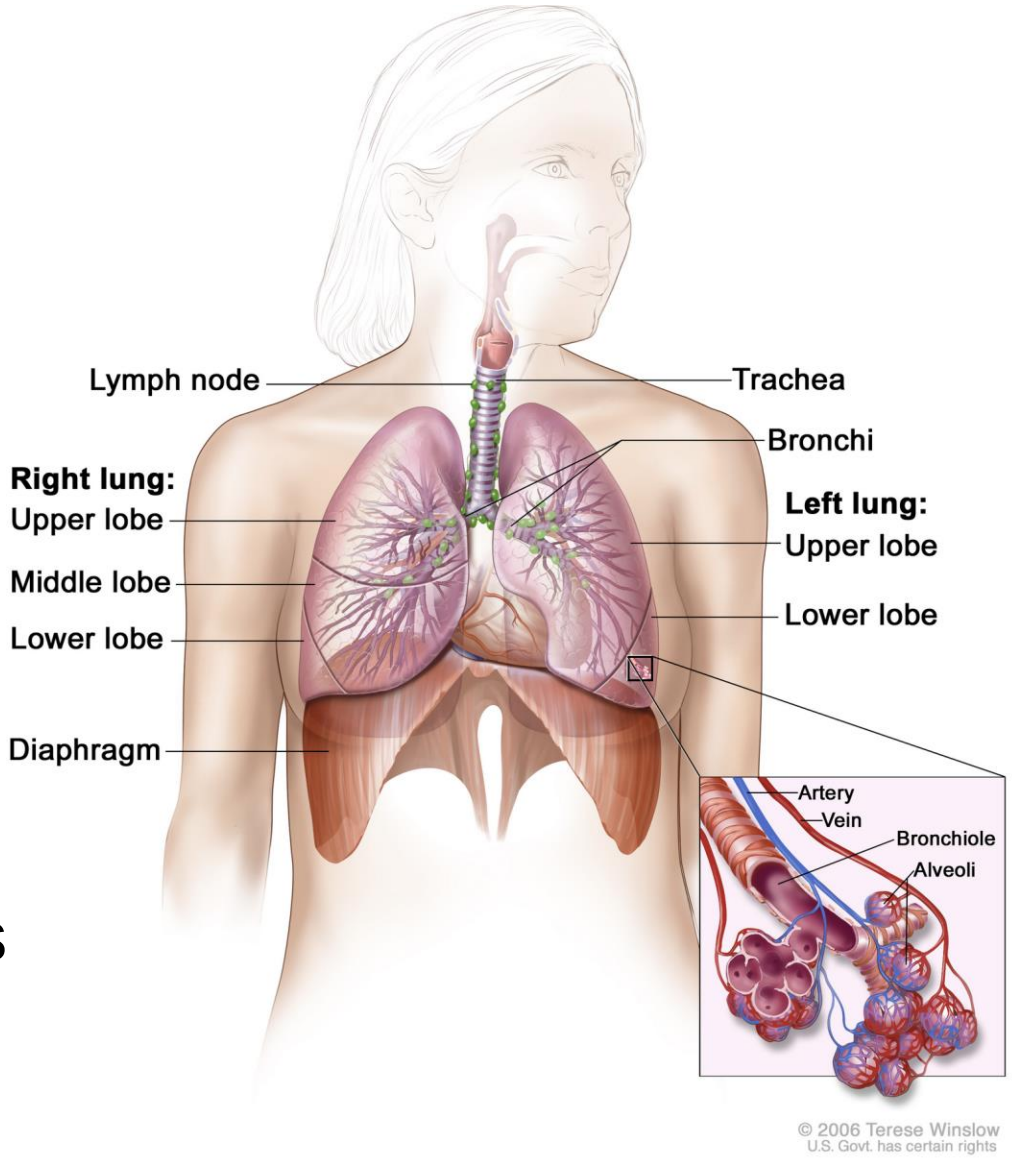
Respiratory Disease Overview

- Asthma, chronic obstructive pulmonary disease (COPD), lung cancer, interstitial lung disease
- A leading cause of worldwide mortality and morbidity
- Children and older adults are most susceptible



Global Burden of Respiratory Disease

Leading causes 1990	Percentage of DALYs 1990	Leading causes 2019	Percentage of DALYs 2019	Percentage change in number of DALYs, 1990–2019	Percentage change in age-standardised DALY rate, 1990–2019
1 Neonatal disorders	10·6 (9·9 to 11·4)	1 Neonatal disorders	7·3 (6·4 to 8·4)	−32·3 (−41·7 to −20·8)	−32·6 (−42·1 to −21·2)
2 Lower respiratory infections	8·7 (7·6 to 10·0)	2 Ischaemic heart disease	7·2 (6·5 to 7·9)	50·4 (39·9 to 60·2)	−28·6 (−33·3 to −24·2)
3 Diarrhoeal diseases	7·3 (5·9 to 8·8)	3 Stroke	5·7 (5·1 to 6·2)	32·4 (22·0 to 42·2)	−35·2 (−40·5 to −30·5)
4 Ischaemic heart disease	4·7 (4·4 to 5·0)	4 Lower respiratory infections	3·8 (3·3 to 4·3)	−56·7 (−64·2 to −47·5)	−62·5 (−69·0 to −54·9)
5 Stroke	4·2 (3·9 to 4·5)	5 Diarrhoeal diseases	3·2 (2·6 to 4·0)	−57·5 (−66·2 to −44·7)	−64·6 (−71·7 to −54·2)
6 Congenital birth defects	3·2 (2·3 to 4·8)	6 COPD	2·9 (2·6 to 3·2)	25·6 (15·1 to 46·0)	−39·8 (−44·9 to −30·2)
7 Tuberculosis	3·1 (2·8 to 3·4)	7 Road injuries	2·9 (2·6 to 3·3)	2·4 (−6·9 to 10·8)	−31·0 (−37·1 to −23·4)
8 Road injuries	2·7 (2·6 to 3·0)	8 Diabetes	2·8 (2·5 to 3·1)	147·9 (135·9 to 158·9)	24·4 (18·5 to 29·7)
9 Measles	2·7 (0·9 to 5·6)	9 Low back pain	2·5 (1·9 to 3·1)	46·9 (43·3 to 50·5)	−16·3 (−17·1 to −15·5)
10 Malaria	2·5 (1·4 to 4·1)	10 Congenital birth defects	2·1 (1·7 to 2·6)	−37·3 (−50·6 to −12·8)	−40·0 (−52·7 to −17·1)
11 COPD	2·3 (1·9 to 2·5)	11 HIV/AIDS	1·9 (1·6 to 2·2)	127·7 (97·3 to 171·7)	58·5 (37·1 to 89·2)
12 Protein-energy malnutrition	2·0 (1·6 to 2·7)	12 Tuberculosis	1·9 (1·7 to 2·0)	−41·0 (−47·2 to −33·5)	−62·8 (−66·6 to −58·0)
13 Low back pain	1·7 (1·2 to 2·1)	13 Depressive disorders	1·8 (1·4 to 2·4)	61·1 (56·9 to 65·0)	−1·8 (−2·9 to −0·8)
14 Self-harm	1·4 (1·2 to 1·5)	14 Malaria	1·8 (0·9 to 3·1)	−29·4 (−56·9 to 6·6)	−37·8 (−61·9 to −6·2)
15 Cirrhosis	1·3 (1·2 to 1·5)	15 Headache disorders	1·8 (0·4 to 3·8)	56·7 (52·4 to 62·1)	1·1 (−4·2 to 2·9)
16 Meningitis	1·3 (1·1 to 1·5)	16 Cirrhosis	1·8 (1·6 to 2·0)	33·0 (22·4 to 48·2)	−26·8 (−32·5 to −19·0)
17 Drowning	1·3 (1·1 to 1·4)	17 Lung cancer	1·8 (1·6 to 2·0)	69·1 (53·1 to 85·4)	−16·2 (−24·0 to −8·2)
18 Headache disorders	1·1 (0·2 to 2·4)	18 Chronic kidney disease	1·6 (1·5 to 1·8)	93·2 (81·6 to 105·0)	6·3 (0·2 to 12·4)
19 Depressive disorders	1·1 (0·8 to 1·5)	19 Other musculoskeletal	1·6 (1·2 to 2·1)	128·9 (122·0 to 136·3)	30·7 (27·6 to 34·3)
20 Diabetes	1·1 (1·0 to 1·2)	20 Age-related hearing loss	1·6 (1·2 to 2·1)	82·8 (75·2 to 88·9)	−1·8 (−3·7 to −0·1)
21 Lung cancer	1·0 (1·0 to 1·1)	21 Falls	1·5 (1·4 to 1·7)	47·1 (31·5 to 61·0)	−14·5 (−22·5 to −7·4)
22 Falls	1·0 (0·9 to 1·2)	22 Self-harm	1·3 (1·2 to 1·5)	−5·6 (−14·2 to 3·7)	−38·9 (−44·3 to −33·0)
23 Dietary iron deficiency	1·0 (0·7 to 1·3)	23 Gynaecological diseases	1·2 (0·9 to 1·5)	48·7 (45·8 to 51·8)	−6·8 (−8·7 to −4·9)
24 Interpersonal violence	0·9 (0·9 to 1·0)	24 Anxiety disorders	1·1 (0·8 to 1·5)	53·7 (48·8 to 59·1)	−0·1 (−1·0 to 0·7)
25 Whooping cough	0·9 (0·4 to 1·7)	25 Dietary iron deficiency	1·1 (0·8 to 1·5)	13·8 (10·5 to 17·2)	−16·4 (−18·7 to −14·0)
27 Age-related hearing loss	0·8 (0·6 to 1·1)	26 Interpersonal violence	1·1 (1·0 to 1·2)	10·2 (3·2 to 19·2)	−23·8 (−28·6 to −17·8)
29 Chronic kidney disease	0·8 (0·8 to 0·9)	40 Meningitis	0·6 (0·5 to 0·8)	−51·3 (−59·4 to −42·0)	−57·2 (−64·4 to −48·6)
30 HIV/AIDS	0·8 (0·6 to 1·0)	41 Protein-energy malnutrition	0·6 (0·5 to 0·7)	−71·1 (−79·6 to −59·7)	−74·5 (−82·0 to −64·5)
32 Gynaecological diseases	0·8 (0·6 to 1·0)	46 Drowning	0·5 (0·5 to 0·6)	−60·6 (−65·2 to −53·6)	−68·2 (−71·9 to −62·8)
34 Anxiety disorders	0·7 (0·5 to 1·0)	55 Whooping cough	0·4 (0·2 to 0·7)	−54·5 (−74·6 to −16·9)	−56·3 (−75·6 to −20·3)
35 Other musculoskeletal	0·7 (0·5 to 1·0)	71 Measles	0·3 (0·1 to 0·6)	−89·8 (−92·3 to −86·8)	−90·4 (−92·8 to −87·5)

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From The Lancet Global Burden of Disease (2020)

Environmental Risk Factors for Respiratory Disease

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Images from: lungdiseasenews.com, Getty images, Dartmouth electron microscope facility

Environment and Respiratory Health

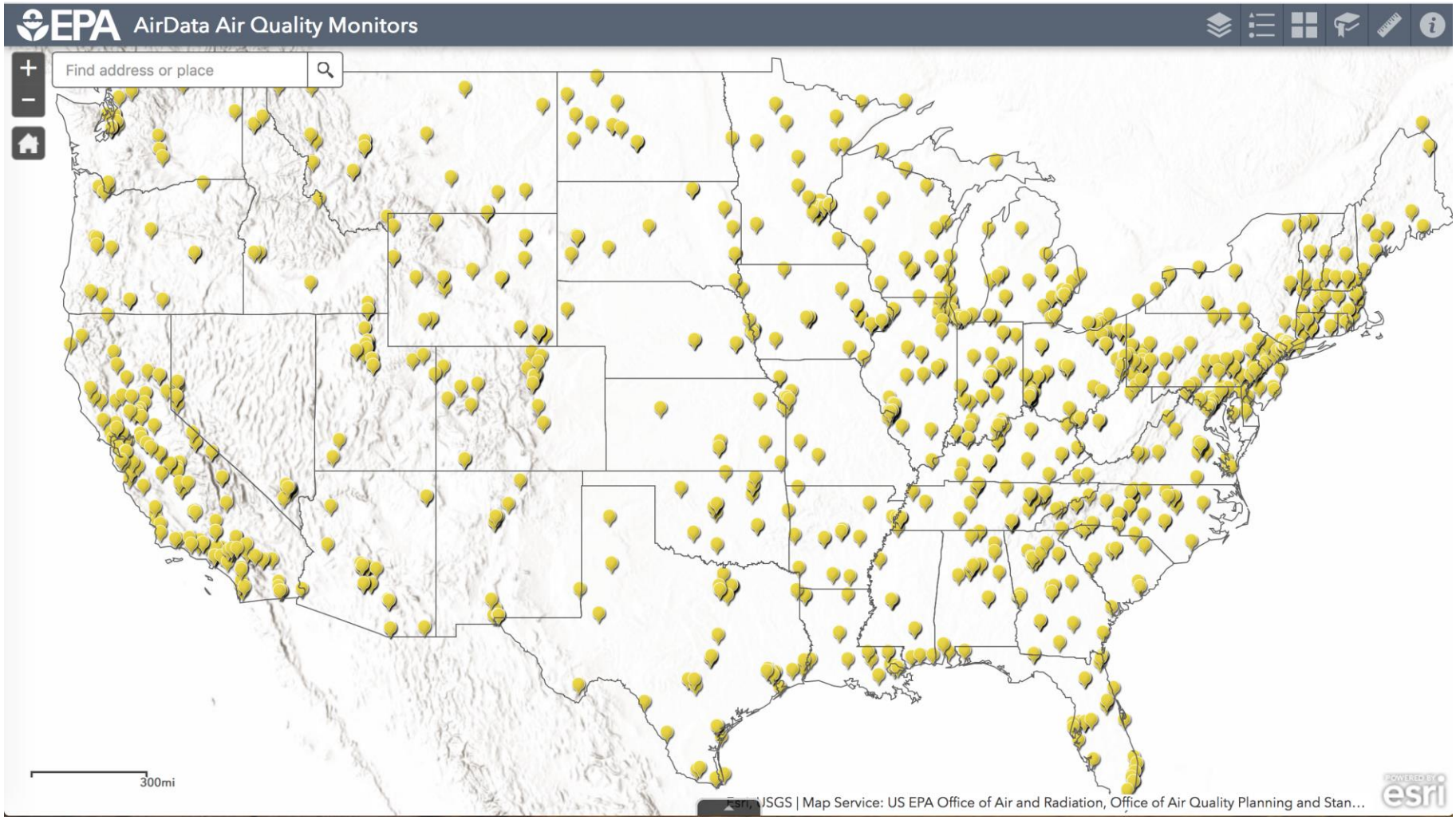
- Need more individual-level large population studies
  - Avoid ecological fallacy; account for individual risk factors

- Improved exposure assessment
  - Better ways to measure exposure, where ground-based measurement is lacking

- Explore intersection between individual and community-characteristics of risk

- Identify unknown exposure-response curves with high vulnerability populations

Locations of AQS Monitors



https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors

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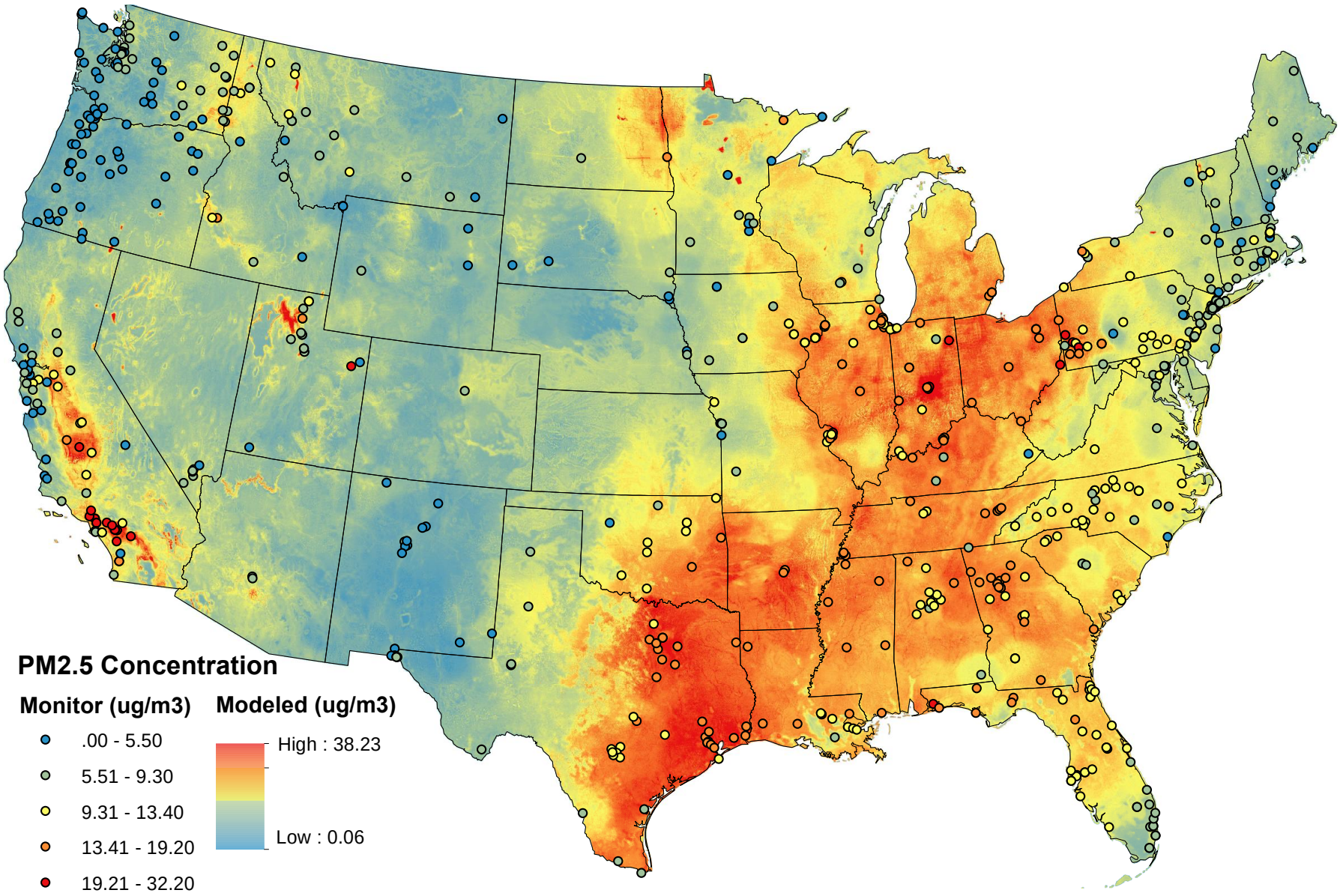
SEDAC Air Pollution Data



Air Pollution Exposure

- Earth data provided by NASA and SEDAC
  - $PM_{2.5}$; also available for O_3 and NO_2
- High resolution modeled output (1x1km)
  - GAM statistical models that include satellite data, land-use, meteorology, chemical transport, etc.
  - R2 of 0.86 for PM2.5
- Geographically complete: contiguous U.S. (2000-2016)

Di et al., 2019. An Ensemble-based Model of PM2.5 Concentration Across the Contiguous United States with High Spatiotemporal Resolution. *Env Int.*

Our Scientific Question: Assess Air Pollution Mortality Risk for Individuals with Existing Respiratory Diseases

- Does this highly vulnerable population with respiratory disease show elevated mortality risk from air pollution?

- Does the presence of multiple comorbidities plus existing respiratory disease affect air pollution risk?

Important for determining the efficacy of air quality regulations and standards

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The VHA COPD Patient Cohort

- All Veterans with doubly diagnosed COPD from 2016-2019 (N=1.12 million)
- High representation by race, rurality, area deprivation
- Skews male and older

	N (%)
Age (mean±SD)	63.5 ± 11.8
Sex	
Male	1,102,931 (95.3)
Female	54,207 (4.7)
Race	
White	901,281 (77.9)
Black	153,386 (13.3)
American Indian	11,571 (1.0)
Asian	4,844 (0.4)
Native Hawaiian	9,161 (0.8)
Unknown	76,925 (6.7)
ADI	
≤20	99,849 (8.6)
21-40	195,643 (16.9)
41-60	279,588 (24.2)
61-80	203,754 (26.2)
81-100	279,334 (24.1)
Rurality	
Urban	684,685 (59.2)
Rural	452,055 (39.1)
Highly rural	19,109 (1.7)

Brief Approach

- **Main outcome**: mortality
- **Main exposure**: 5-year average $PM_{2.5}$ at patient household

- **Statistical Model**: Nested logistic regression modeling
  - Model 1: Adjusted for age, sex, lat, lon
  - Model 2: Model 1 + race, smoking status
  - Model 3: Model 2 + neighborhood SES + rurality
- **Effect Modification**: Stratification by comorbidities

So, What Did We Find?

- A total of **382,258 mortalities** in the U.S.

- $PM_{2.5}$ exposure **highest in Black individuals** (8.97 ug/m^3) and **lowest in White individuals** (8.07 ug/m^3)

- Estimated a near 4% increase in mortality for each 1 ug/m^3 increase in long-term $PM_{2.5}$ exposure
  - *Substantially higher than estimates for general populations*

N	Model 1 Adjusted for Age + Sex + Lat + Lon aOR (95% CI)	Model 2 (Model 1 + Race + Smoking Status) aOR (95% CI)	Model 3 (Model 2 + SES + Rurality) aOR (95% CI)
1,124,973	1.038 (1.035-1.040)	1.038 (1.035-1.041)	1.0290 (1.026-1.032)

The Impact of Multiple Comorbidities

Native Hawaiian or Pacific Islander	8,136 (0.7)	1.01 (0.98-1.04)	0.1525
ADI 1st Quartile	271,407 (24.4)	1.03 (1.02-1.03)	ref
Male	1,1074,877 (95.6)	1.03 (1.03-1.03)	0.0014
Female	50,072 (4.5)	1.00 (1.00-1.02)	ref
White	879,584 (78.2)	1.03 (1.03-1.03)	ref
Black or African American	149,124 (13.3)	1.03 (1.02-1.04)	0.4785
Asian	3,527 (0.3)	1.06 (1.02-1.11)	0.1416
American Indian or Alaska Native	11,080 (1.0)	1.01 (0.99-1.04)	0.1368
Native Hawaiian or Pacific Islander	8,136 (0.7)	1.01 (0.98-1.04)	0.1525
ADI 1st Quartile	271,407 (24.4)	1.03 (1.02-1.03)	ref

- Elevated risk from patients with COPD plus a) lung cancer, b) coronary artery disease, c) chronic kidney disease

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Anything Else?

- Observed racial disparities
  - Individuals residing in **most deprived communities** had significantly **higher risk** than those in least deprived communities

- Rural risk slightly higher, but not significantly

Brief Conclusions

- Air pollution risks for people with COPD substantially higher than general population
- Earth Data improved our ability to assess rare populations and geographies
- **Future Questions: Can Earth Data help identify risk from sourced air pollution?**

Minneapolis shrouded in air pollution during a wintertime inversion event (Jan 9, 2023)

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