Environmental Impacts on Mortality in the US

2010 – 2019

Shuai Zhou

Global Development, Cornell University

In collaboration with Chuan Liao, Ziqing Wei, and Guangqing Chi

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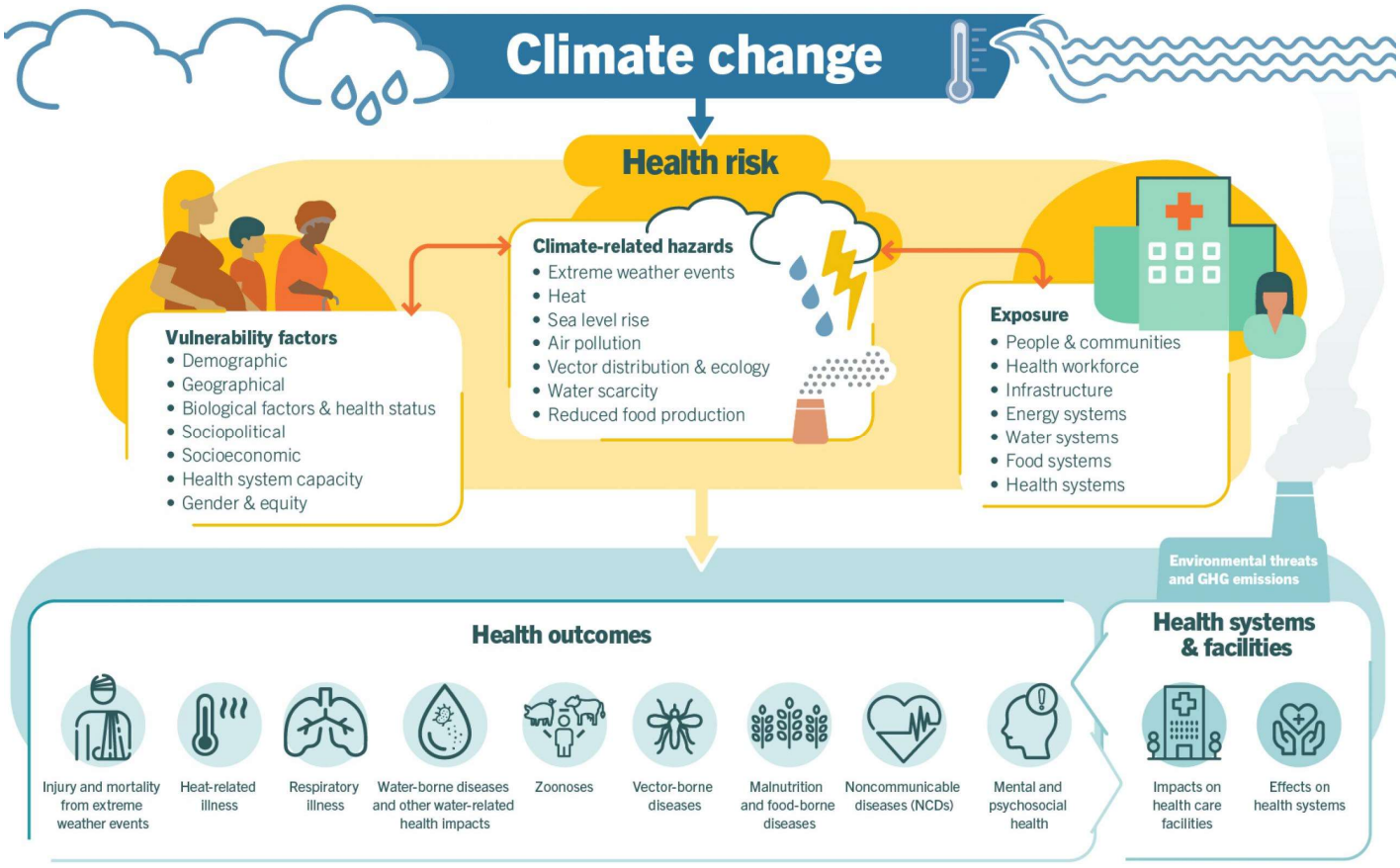
Outline

1. Background
2. Knowledge gaps
3. Research objectives
4. Methods
5. Results
6. Discussion

Environmental change burdens health



Source: WHO

Existing studies emphasized SDOH

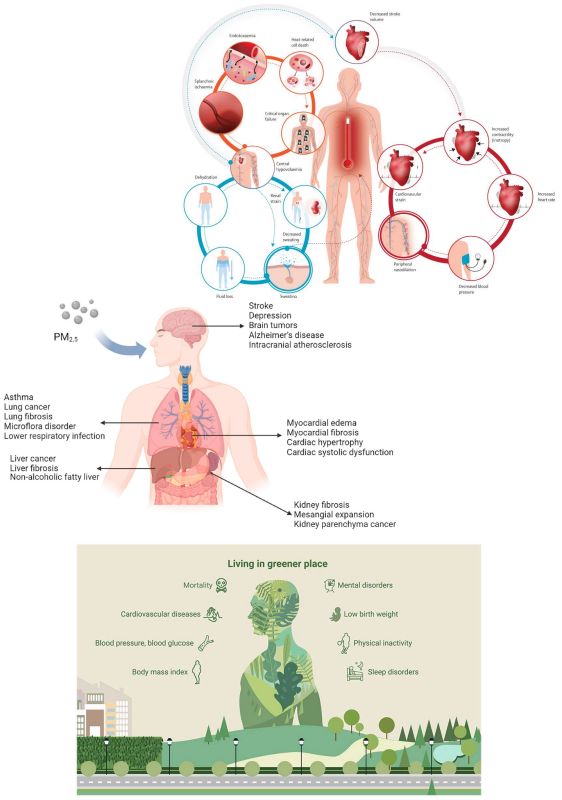
Five components of social determinants of health (SDOH):

- Economic stability (Murray, 2003; Sommers et al., 2017)
- Education access and quality (Vable et al., 2020)
- Health care access and quality (Herman et al., 2011)
- Neighborhood and built environment (Penney et al., 2015)
- Social and community context (Clair et al., 2021)

Source: OASH

Related work showed environmental impact

- Rural mortality penalty exists, with such penalty being highest in high-poverty rural communities (Cosby et al., 2019)
- Rising temperature increased mortality in both rural (James, 2014; Rhubart & Santos, 2023) and urban settings (Lowe, 2016; Cleland et al., 2023)
- Air pollution caused cardiovascular and respiratory diseases among people exposed for both short (Ye et al., 2022) and prolonged periods (Raaschou-Nielsen et al., 2023)
- Green space tended to attenuate all-cause and cardiovascular mortality (Coutts et al., 2010)



Source: The Lancet; The Innovation

What we do…

1. Investigate the nonlinear environmental impacts on cause- and age-specific mortality
2. Test whether rural mortality penalty persists across cause- and age-specific mortality

Measure mortality rates using the IHME data

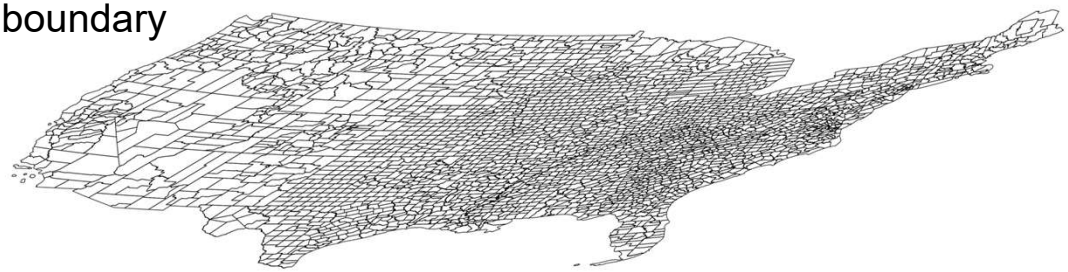
- **Cause-specific mortality rates**
  1. Chronic respiratory (**CR**) diseases
  2. Cardiovascular (**CV**) diseases

- **Age-specific mortality rates**
  1. 0 – 1
  2. 1 – 14
  3. 15 – 64
  4. 65+

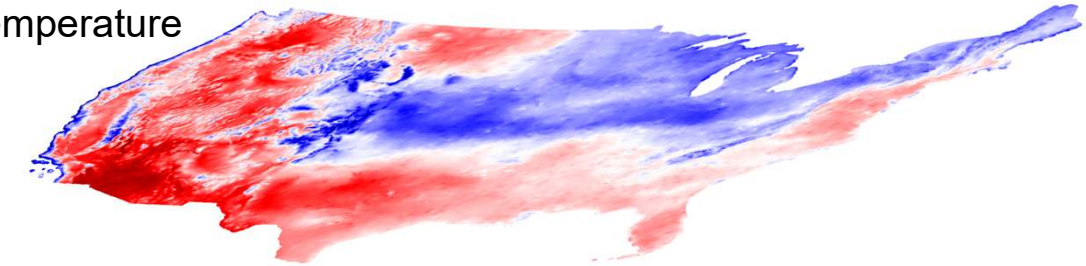
Institute for Health Metrics and Evaluation

Measure environmental factors from grid data

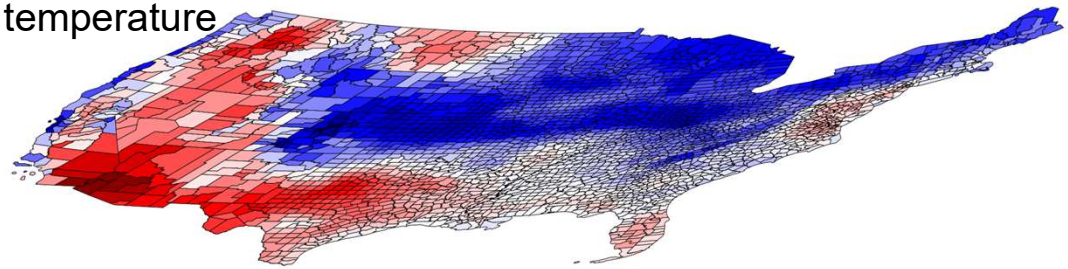
(A) County boundary



(B) Grid temperature



(C) County temperature



Fixed-effects modelling

$$Y_{i,t} = \beta_0 + \beta X_{i,t} + \gamma_i + \delta_t + \varepsilon_{i,t}$$

$Y_{i,t}$ are the mortality of county *i* at time *t*

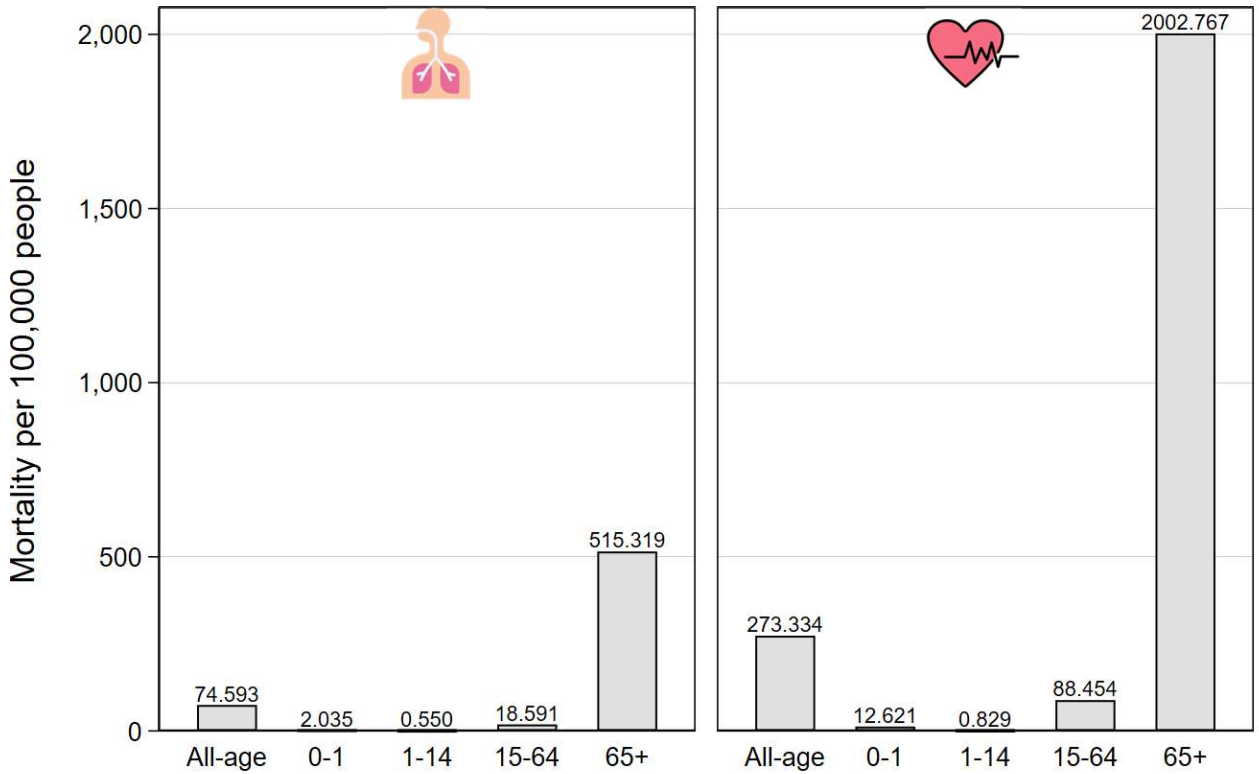
$X_{i,t}$ is a matrix of environmental, socioeconomic, and demographic factors

β_0 and β are intercept and coefficient estimates, respectively

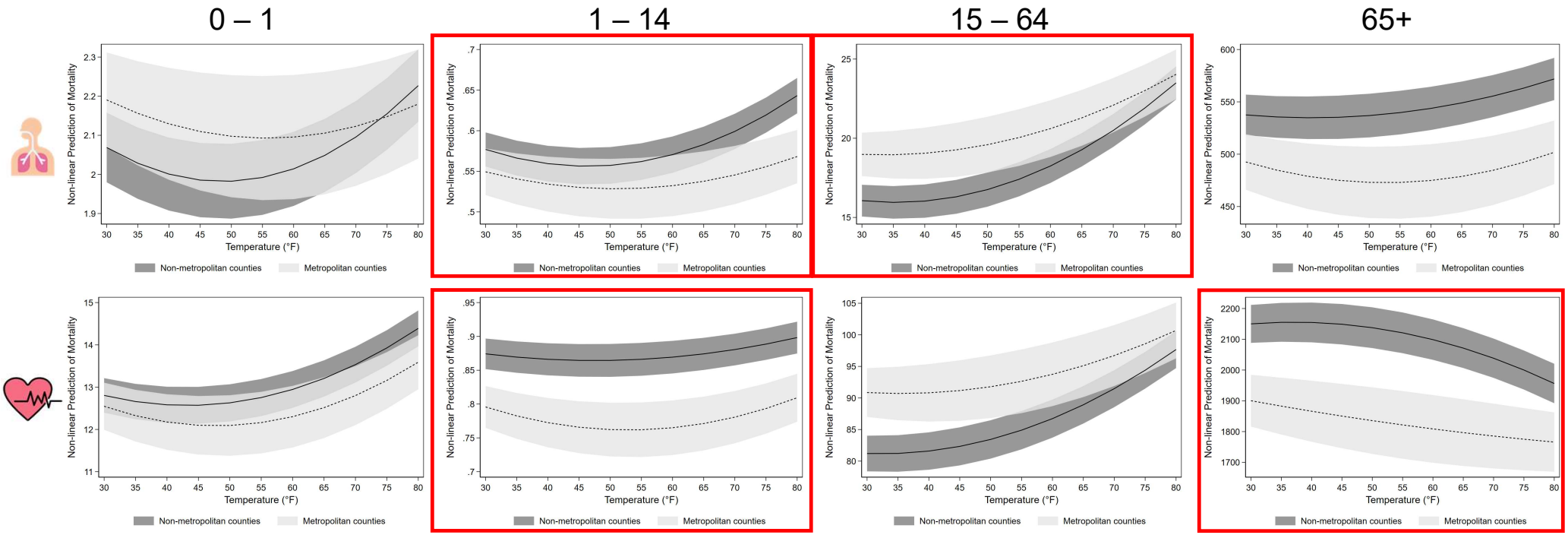
γ_i and δ_t are county and year fixed-effects, respectively

$\varepsilon_{i,t}$ is the error term

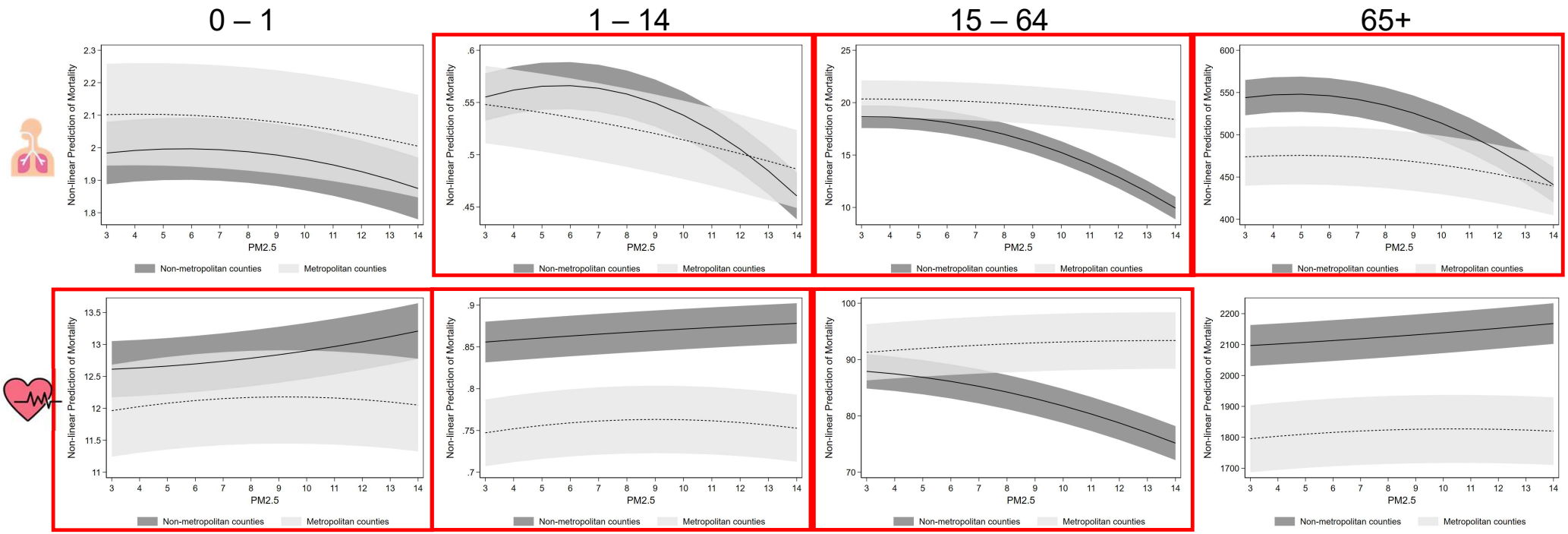
Mortality shows age/cause specific patterns



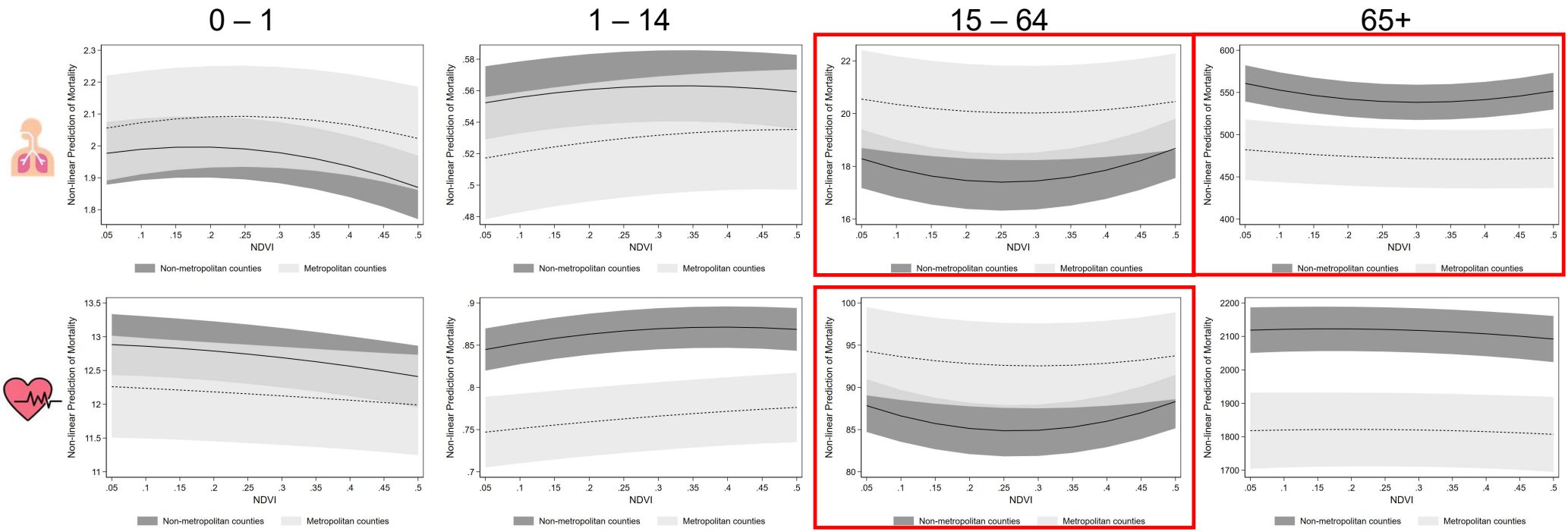
Temperature



PM2.5


0 – 1
1 – 14
15 – 64
65+
Non-linear Prediction of Mortality
PM2.5
Non-metropolitan counties
Metropolitan counties

NDVI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Non-linear Prediction of Mortality
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Takeaways

1. Temperature showed non-linear effects and a rural mortality penalty for teenagers and adults, but not for the elderly

2. Air quality lowered CR-related mortality but increased CV-related mortality among infants and teenagers in rural counties and working-age adults in urban counties

3. Greenness coverage influences mortality, but not as much as temperature and air quality did

Implications for research and policy-making

1. Rural mortality penalty exists but not uniformly across all ages or causes of death

2. Policy-making should prioritize addressing the unique health challenges specific to different age groups and regions

3. Additional unobserved behavioral, pathological, and context-specific factors deserve further investigation

    - Exposure avoidance
    - Early warning system
    - Advanced medical treatment
    - Pathological differences between CR and CV diseases

Thank you

Questions?
Email Dr. Shuai Zhou at sz675@cornell.edu

Appendix

Data sources

Variable	Data source
Dependent variable	
Cause-specific mortality rates	Institute for Health Metrics and Evaluation
Environmental factors	
Temperature	Parameter-elevation Regressions on Independent Slopes Model
$PM_{2.5}$	Atmospheric Composition Analysis Group
NDVI	National Center for Atmospheric Research
Sociodemographic factors	
Household income	American Community Survey
% College graduate	American Community Survey
% Health insurance	American Community Survey
County metropolitan status	The US Office of Management and Budget

Descriptive statistics

	N	mean	SD	Min	Max
CR_{All}	33,924	74.593	19.003	18.146	187.262
CR_{0-1}	33,924	2.035	0.593	0.615	5.075
CR_{1-14}	33,924	0.550	0.181	0.174	1.531
CR_{15-64}	33,924	18.591	7.922	3.912	76.537
CR_{65+}	33,924	515.319	133.552	161.624	1,335.552
CV_{All}	33,924	273.334	54.834	73.103	638.873
CV_{0-1}	33,924	12.621	2.979	3.262	25.581
CV_{1-14}	33,924	0.829	0.236	0.302	2.062
CV_{15-64}	33,924	88.454	32.708	20.834	269.208
CV_{65+}	33,924	2,002.767	386.100	652.433	4,912.635
Temperature	34,199	54.945	8.406	31.747	78.809
PM2.5	34,199	7.343	1.696	2.968	14.016
NDVI	34,199	0.239	0.059	0.060	0.523
Income	34,192	65.675	16.103	30.949	184.416
College	34,193	49.951	10.903	6.283	93.302
Insurance	34,193	85.298	6.055	57.300	97.900
Metropolitan county	34,199	0.373	0.484	0.000	1.000

Regression table

	(1) CR_{All}	(2) CV_{All}	(3) CR_{0-1}	(4) CV_{0-1}	(5) CR_{1-14}	(6) CV_{1-14}	(7) CR_{15-64}	(8) CV_{15-64}	(9) CR_{65+}	(10) CV_{65+}
Environmental factors										
Temperature	-0.558***	0.266	-0.024***	-0.117***	-0.007***	-0.003***	-0.268***	-0.469***	-1.947***	8.066***
Temperature^2	0.006***	-0.005*	0.000***	0.001***	0.000***	0.000***	0.004***	0.007***	0.024***	-0.109***
PM2.5	1.835***	0.943**	0.020***	-0.002	0.017***	0.003**	0.502***	0.041	12.146***	4.113
PM2.5^2	-0.205***	-0.073***	-0.002***	0.003**	-0.002***	-0.000	-0.076***	-0.071***	-1.266***	0.139
NDVI	-27.337***	-9.702	0.435***	-0.288	0.090**	0.178***	-10.814***	-33.923***	-210.969***	93.090
NDVI^2	46.061***	11.358	-1.222***	-1.392	-0.135**	-0.228***	21.252***	63.614***	346.655***	-276.673
Interactions										
Temperature * Metro	-0.137	-0.478	0.008	-0.022	0.002*	-0.004**	0.111*	0.113	-2.121*	-12.770***
Temperature^2 * Metro	0.001	0.004	-0.000*	0.000	-0.000**	0.000**	-0.001**	-0.002	0.015	0.127***
PM2.5 * Metro	-1.165***	0.983	-0.012	0.105***	-0.020***	0.005**	-0.406***	0.457*	-7.735***	7.845
PM2.5^2 * Metro	0.138***	0.003	0.001*	-0.009***	0.001***	-0.000***	0.060***	0.052***	0.820***	-0.710**
NDVI * Metro	18.058**	19.244	0.059	-0.162	-0.001	-0.084	5.367*	17.002**	133.751**	-27.376
NDVI^2 * Metro	-36.855**	-34.648	0.193	1.116	0.047	0.175	-11.720**	-35.008**	-246.318**	112.999
Controls										
Income	-0.083***	-0.137***	-0.000	0.005***	-0.000***	0.000***	-0.040***	-0.065***	-0.402***	-0.688***
College	-0.071***	-0.297***	-0.004***	-0.023***	-0.001***	-0.001***	-0.009**	-0.100***	-0.617***	-2.327***
Insurance	-0.018	-0.231***	-0.000	-0.003*	-0.000**	-0.000***	0.078***	0.101***	-0.433***	-2.939***
Age-specific population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	101.016***	328.359***	2.680***	16.932***	0.731***	1.015***	19.665***	100.148***	664.701***	2,446.170***
Observations	33,839	33,839	33,830	33,830	33,830	33,830	33,830	33,830	33,830	33,830
R-squared	0.353	0.389	0.369	0.504	0.463	0.657	0.596	0.386	0.351	0.540
Number of counties	3,078	3,078	3,076	3,076	3,076	3,076	3,076	3,076	3,076	3,076
AIC	157,997	225,600	-76,944	26,158	-174,677	-169,649	86,908	156,934	287,240	365,462
BIC	158,225	225,828	-76,717	26,386	-174,450	-169,422	87,136	157,161	287,468	365,690

***p < 0.001, **p < 0.01, *p < 0.05. AIC = Akaike's information criterion; BIC = Schwartz's Bayesian information criterion