

Disparities in air pollution attributable mortality in the US population by race/ethnicity and sociodemographic factors

In the format provided by the
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Supplementary Materials

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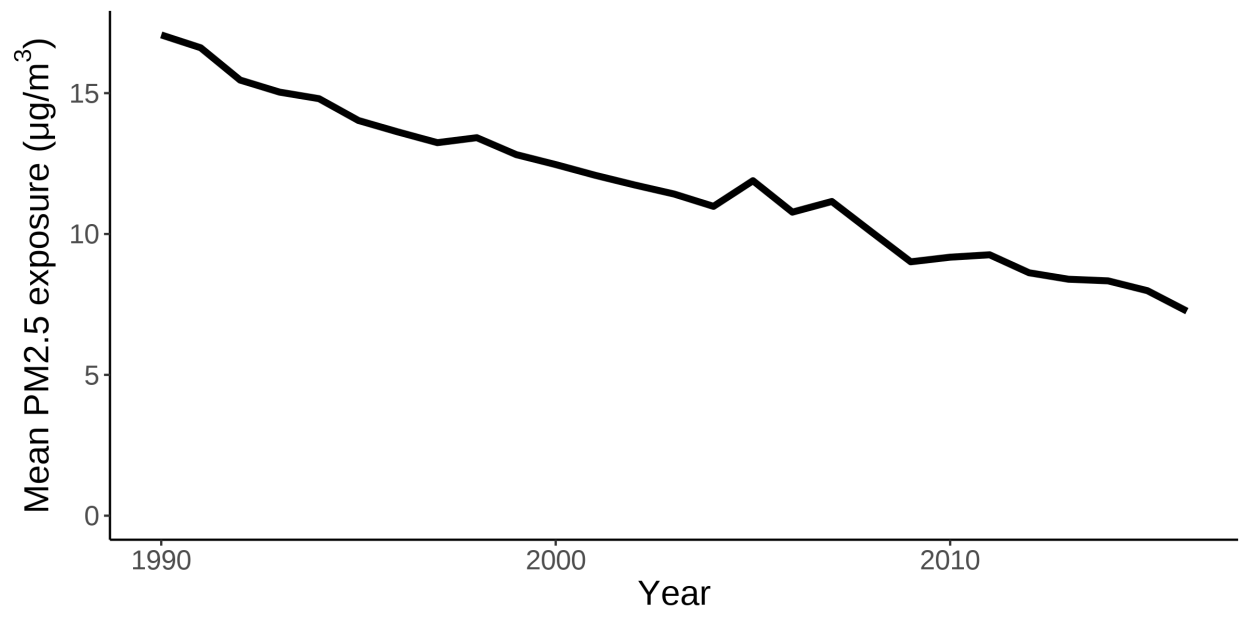
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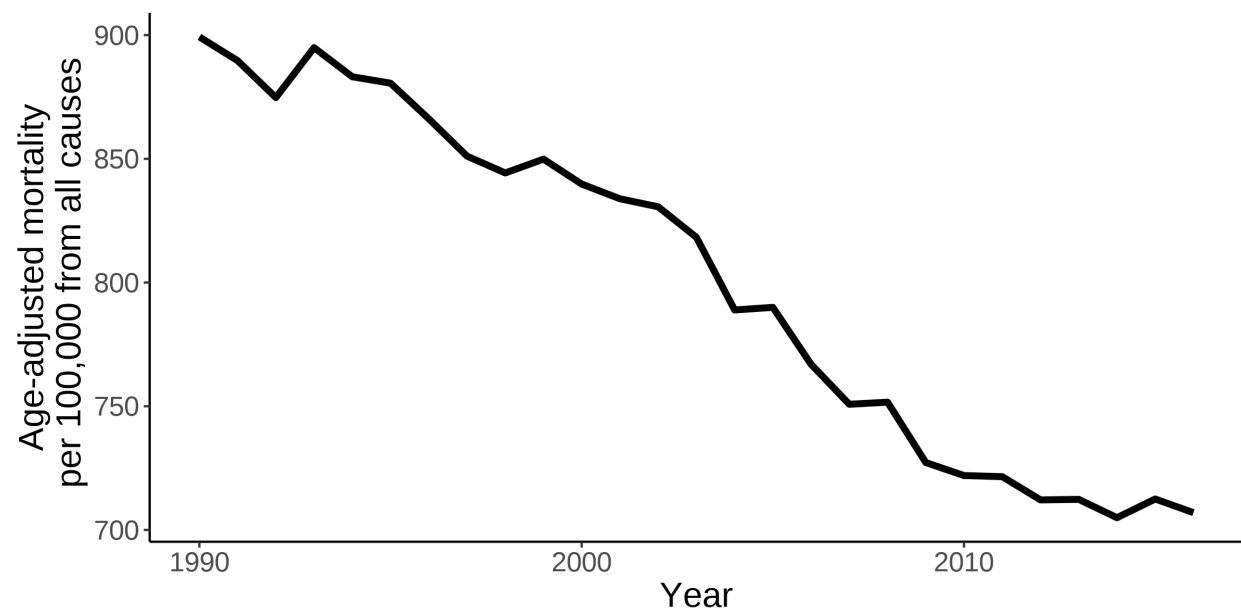
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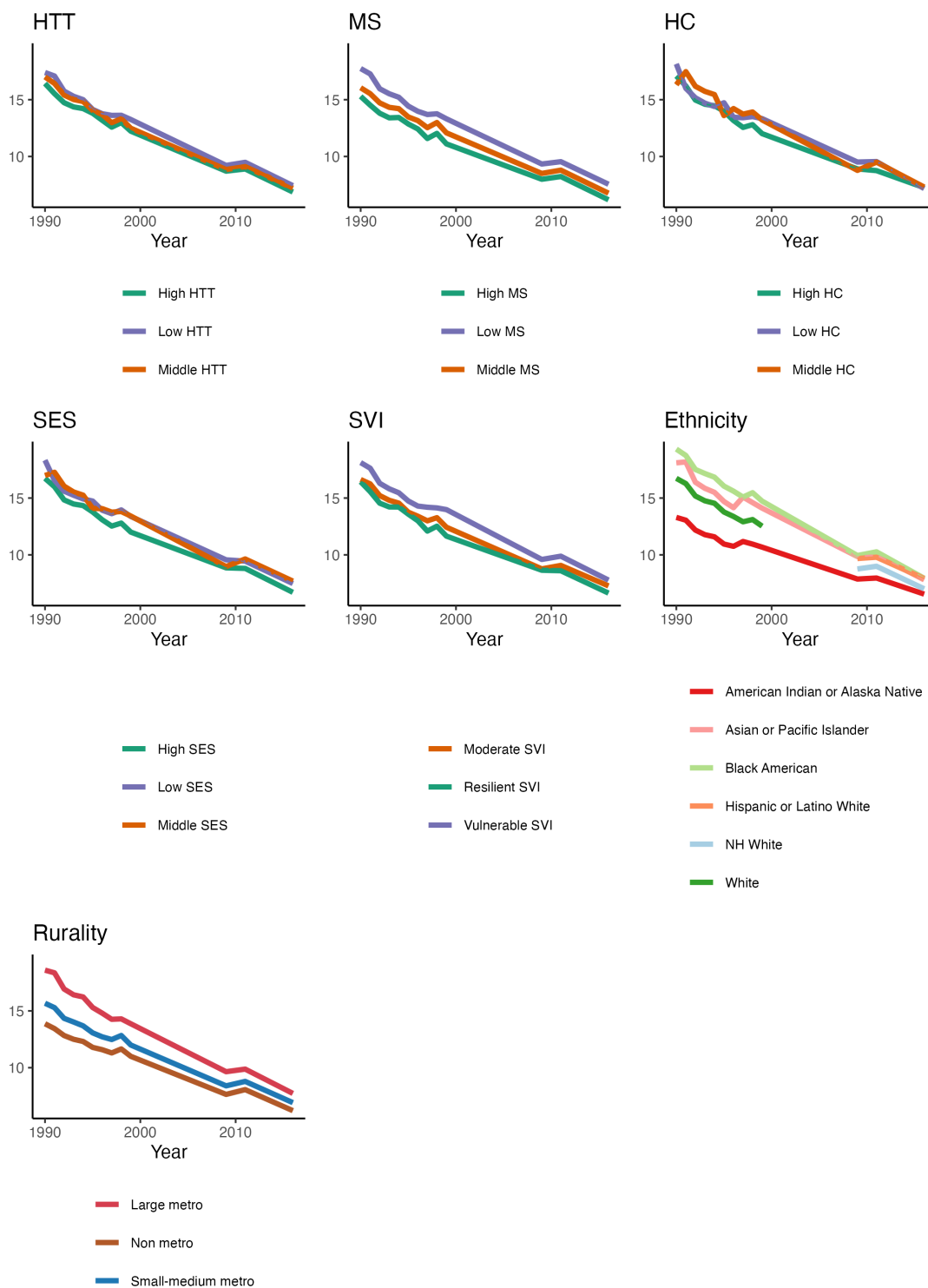
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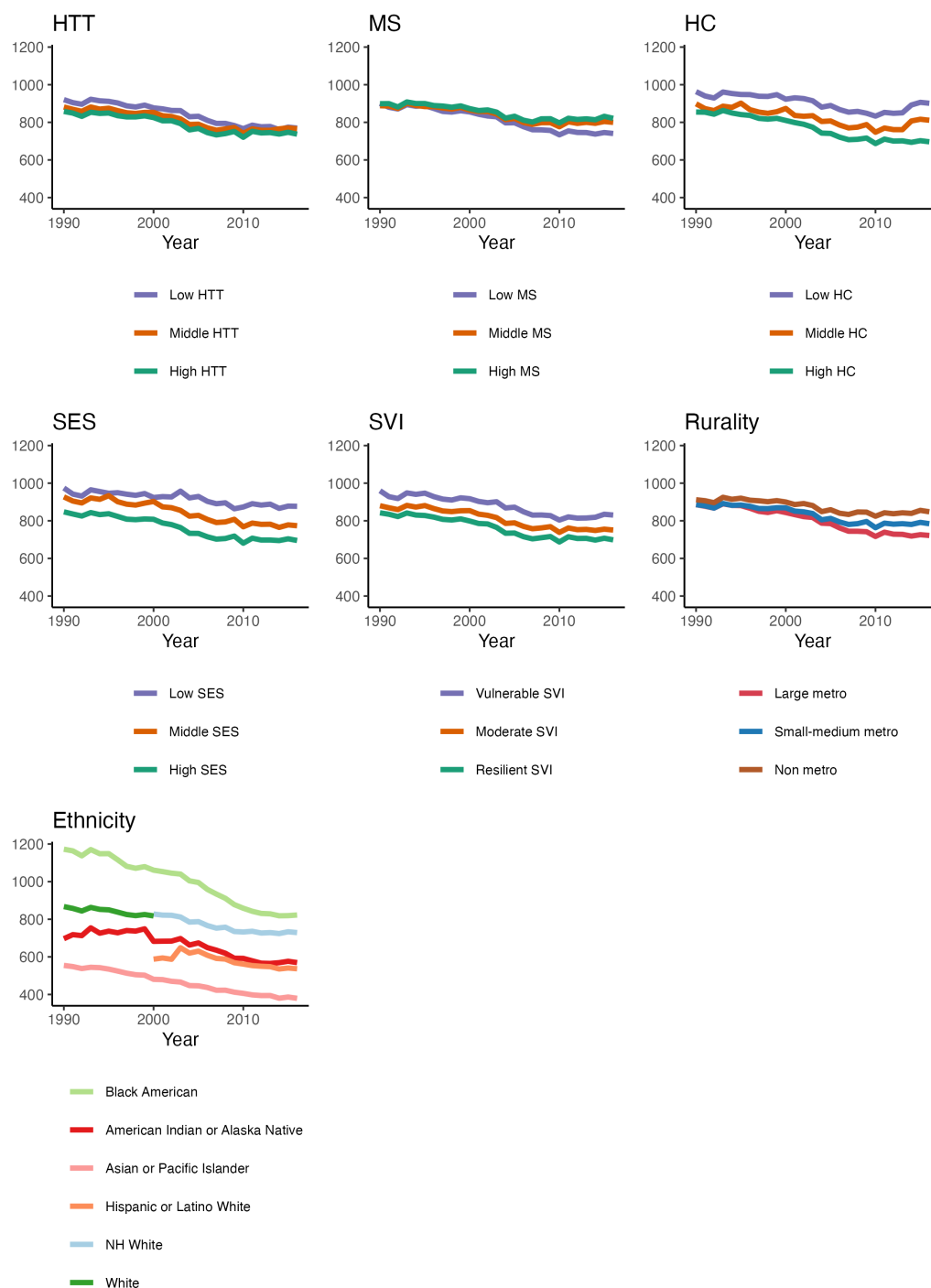


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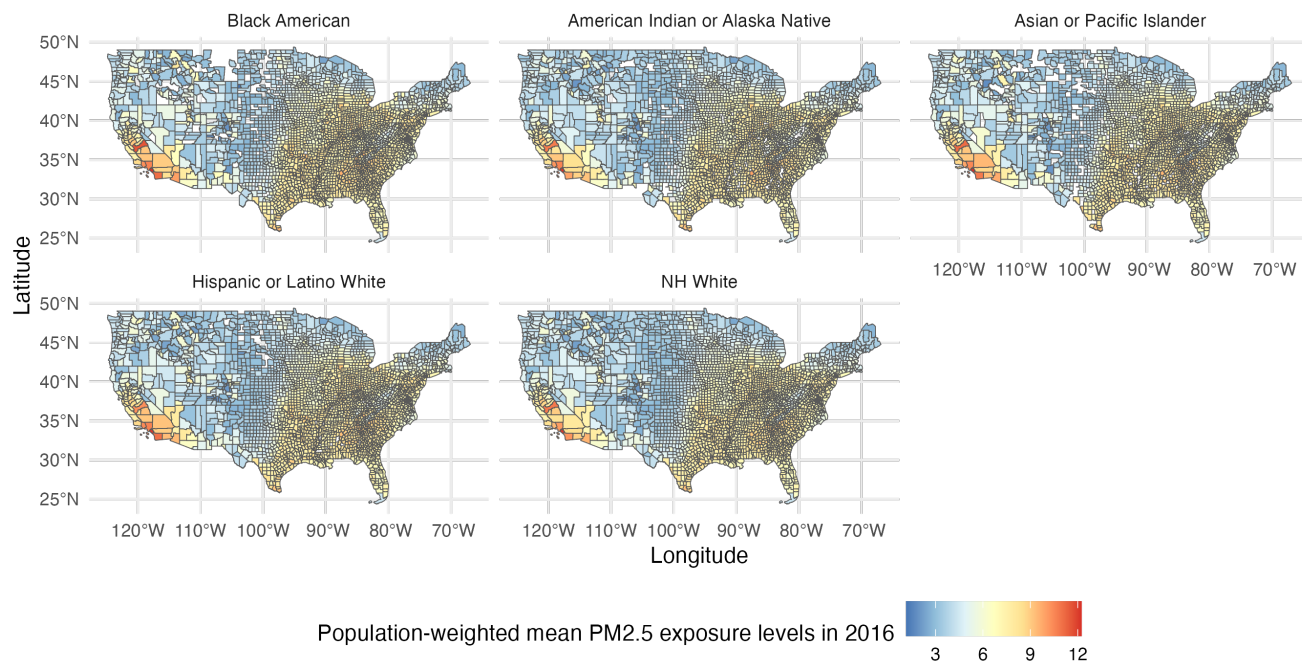
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Abbreviations: SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index, NH=Non-Hispanic.



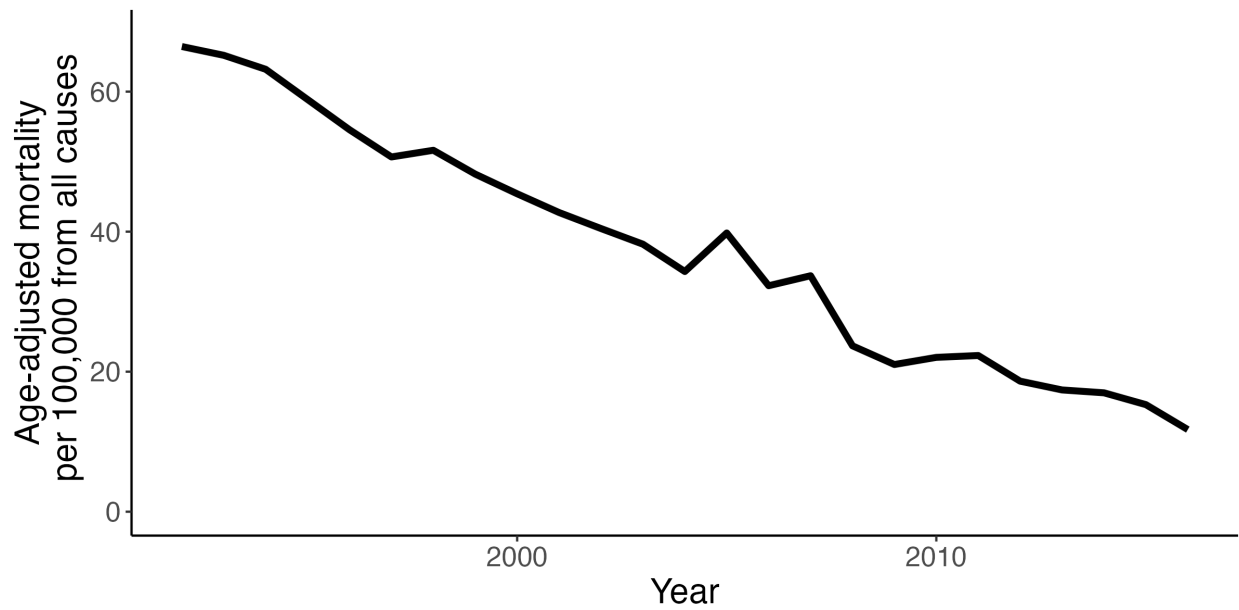
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Abbreviations: SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index, NH=Non-Hispanic.

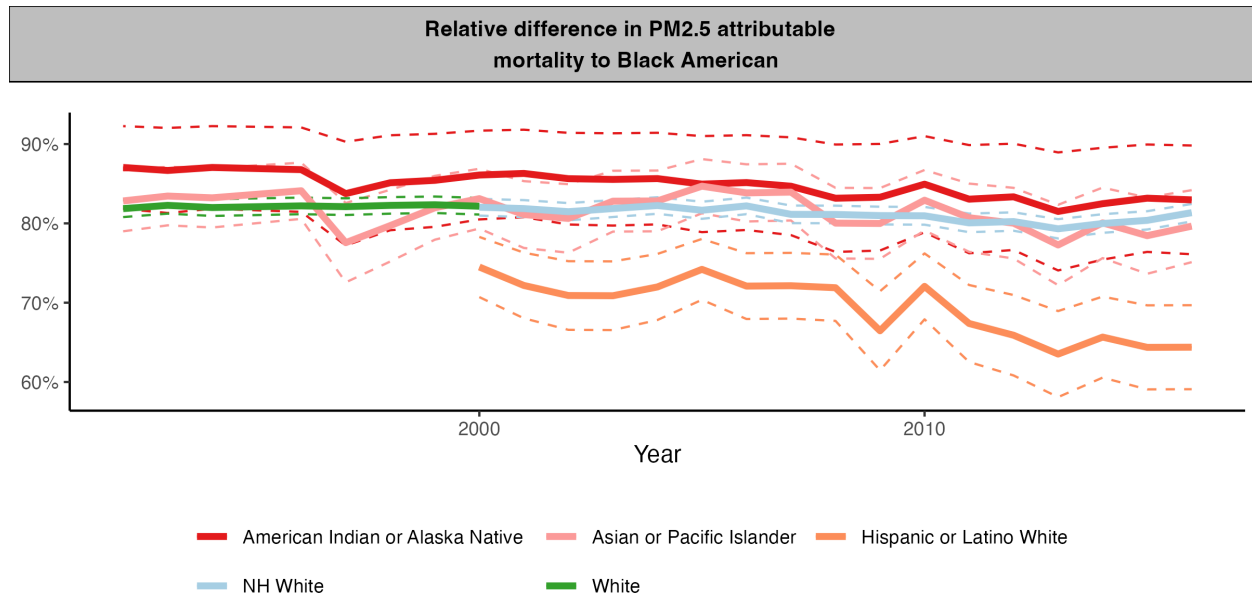


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Abbreviations: NH=Non-Hispanic.

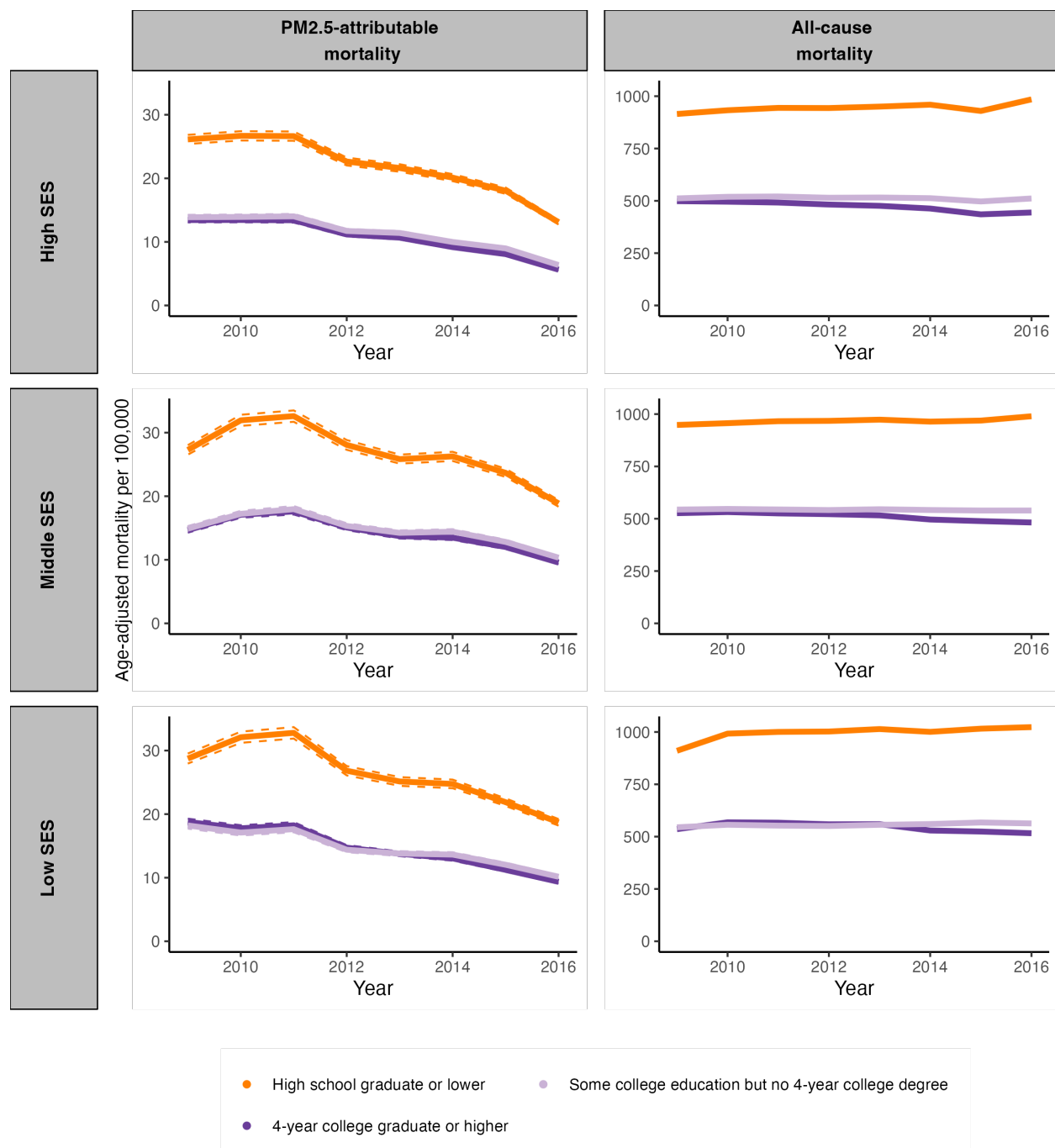


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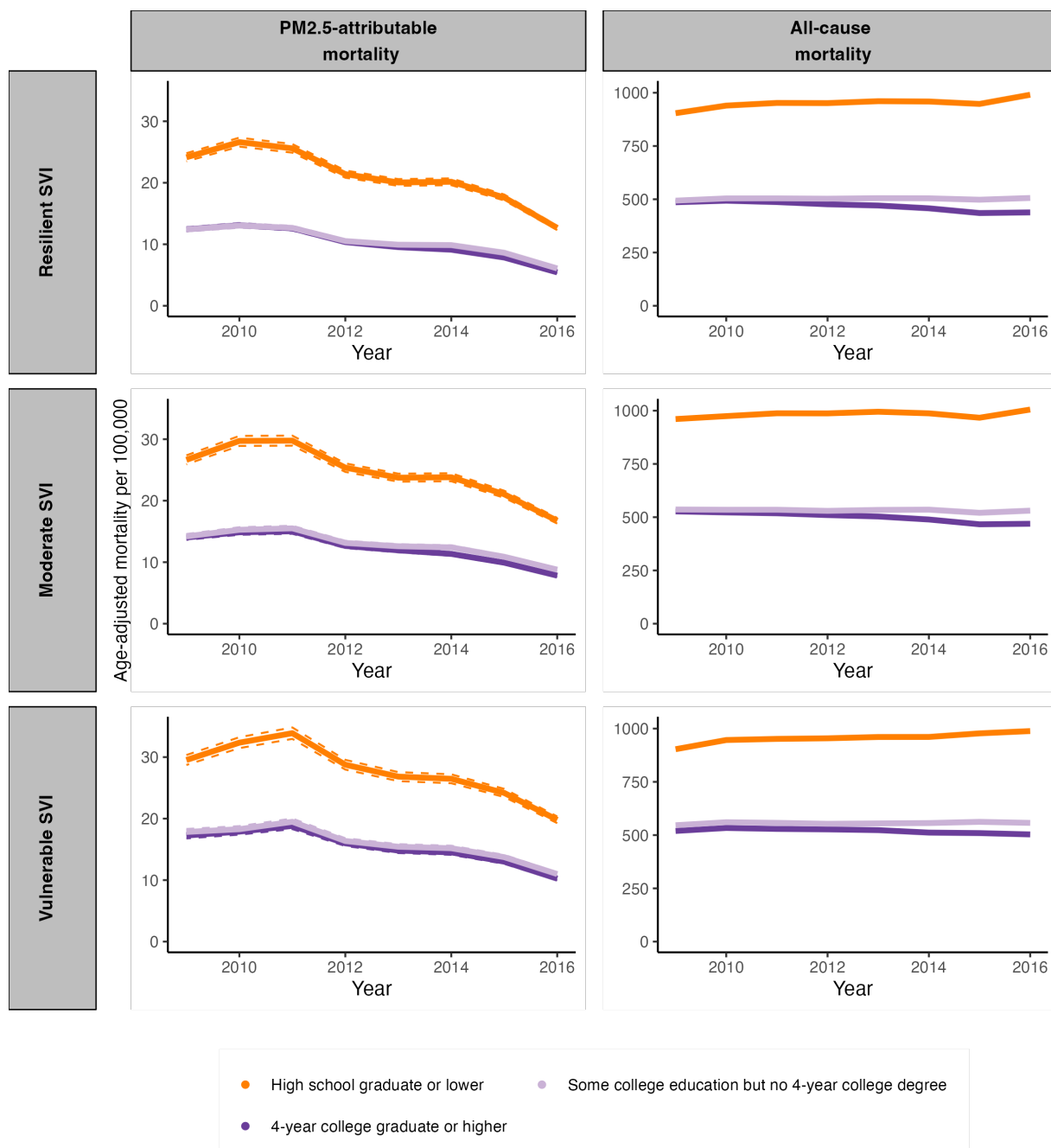
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This figure is for the age group 25+ years and spans the period 1990 to 2016. On average during the period 1990 to 2016, the PM_{2.5}-attributable mortality rate for the “Asian or Pacific Islander” and “American Indian or Alaska Native” population was 81.8% and 85.3% lower, respectively, than for the “Black American” population. The PM_{2.5}-attributable mortality rate for the “White (All Hispanic Origins)” population was 82.0% lower than for the Black American population during the period 1990 to 2000. Lastly, on average during the period 2000 to 2016, the PM_{2.5}-attributable mortality rate for the “NH White” and “Hispanic or Latino White” population was 81.4% and 70.1% lower, respectively, than for the “Black American” population.



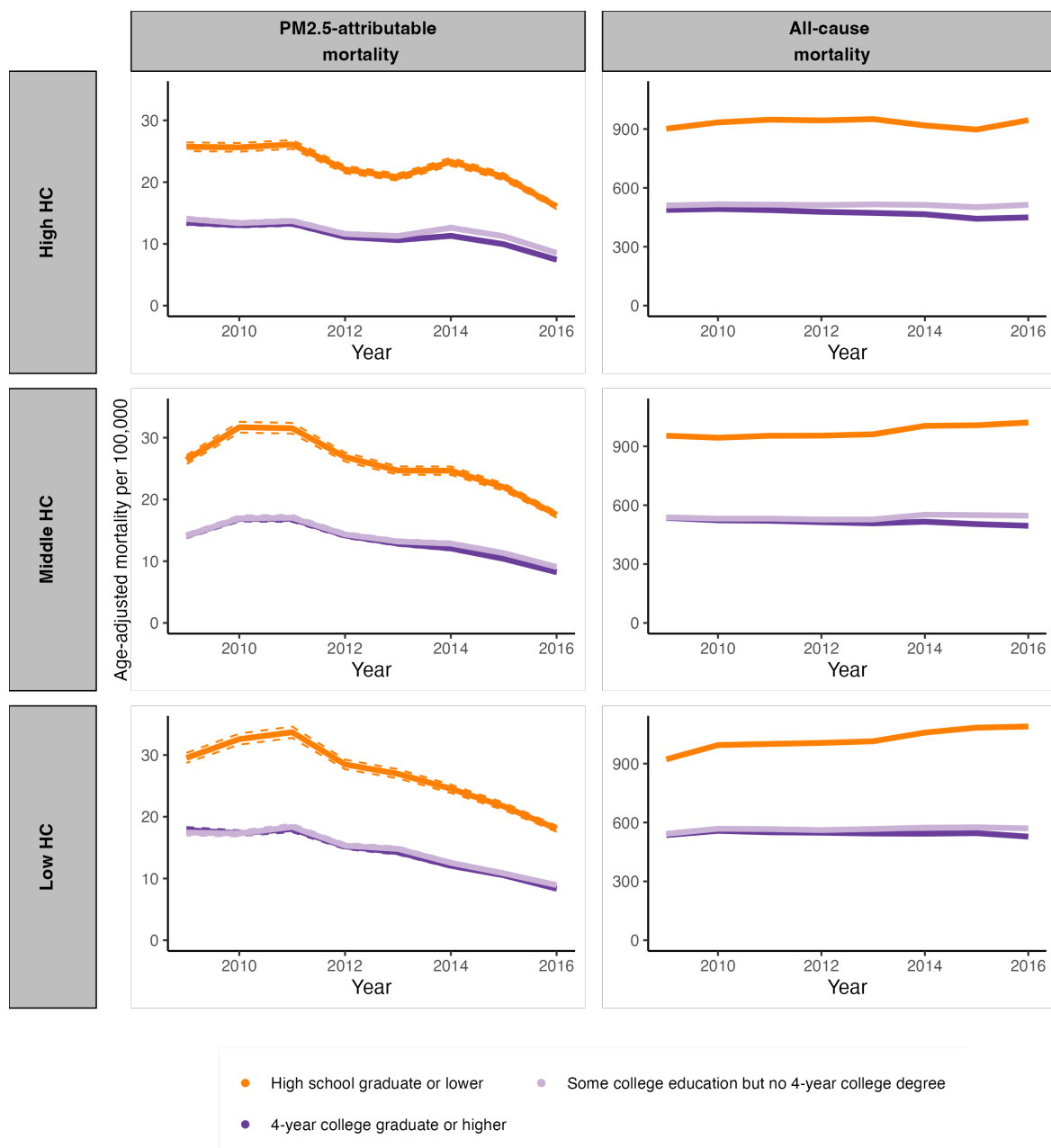
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The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.
Abbreviations: NH=Non-Hispanic, SES = socioeconomic status.



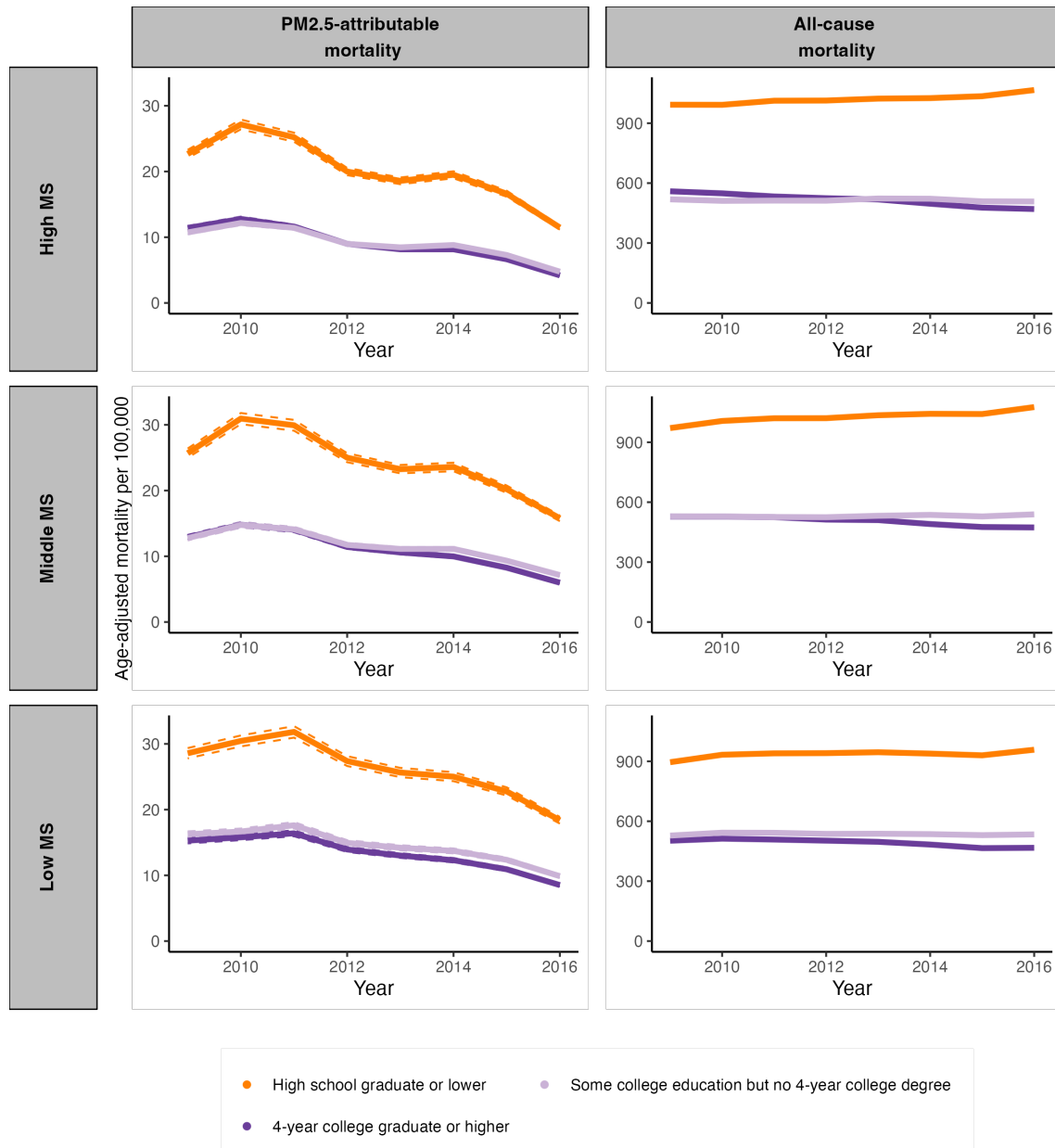
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The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.
Abbreviations: NH=Non-Hispanic.



Supplement Fig. 11. Age-adjusted PM2.5-attributable mortality rate and all-cause mortality rate for each education level stratified by household characteristic.

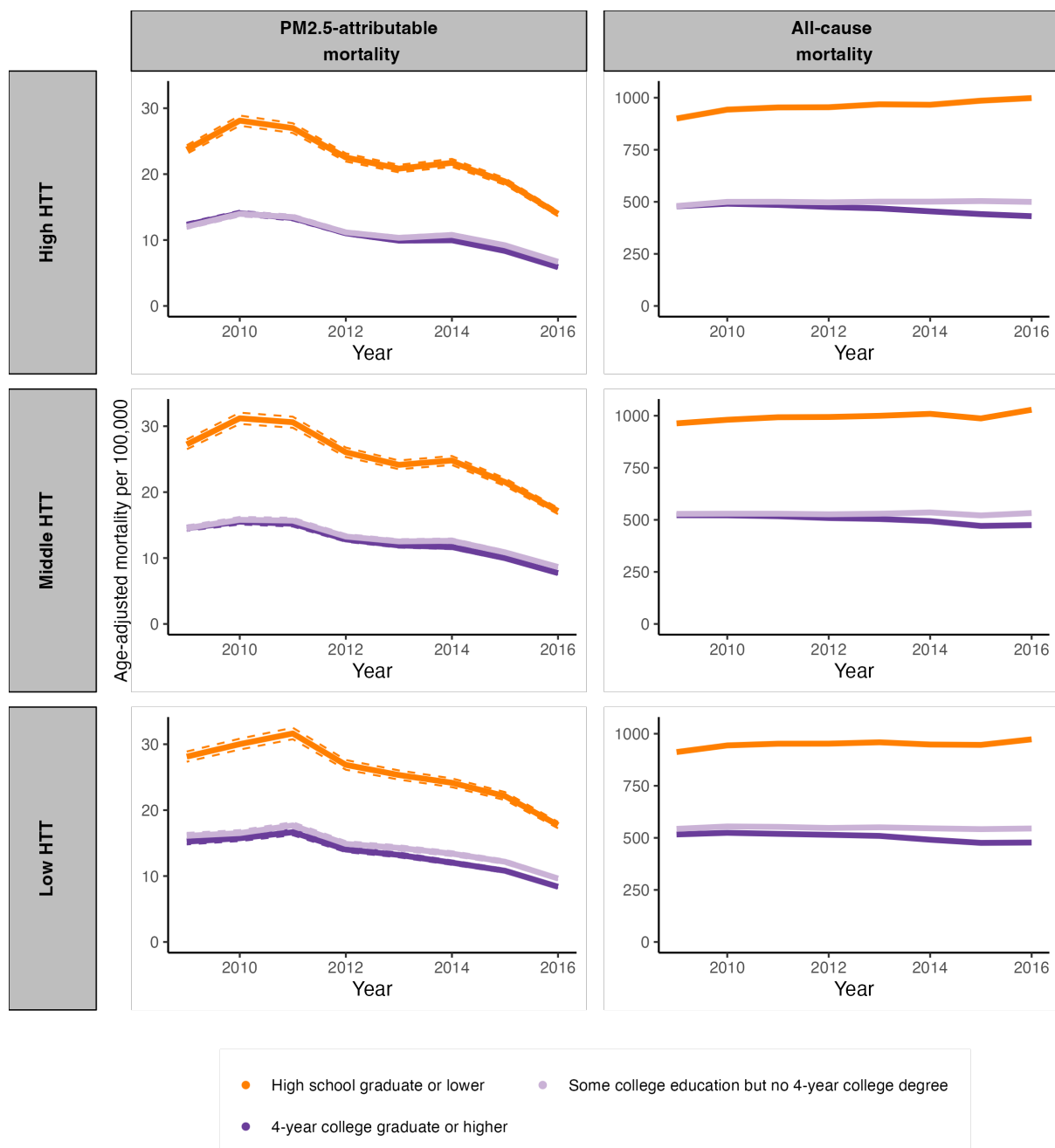
The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.
Abbreviations: NH=Non-Hispanic, HC = household characteristic.



Supplement Fig. 12. Age-adjusted PM_{2.5}-attributable mortality rate and all-cause mortality rate for each education level stratified by minority status.

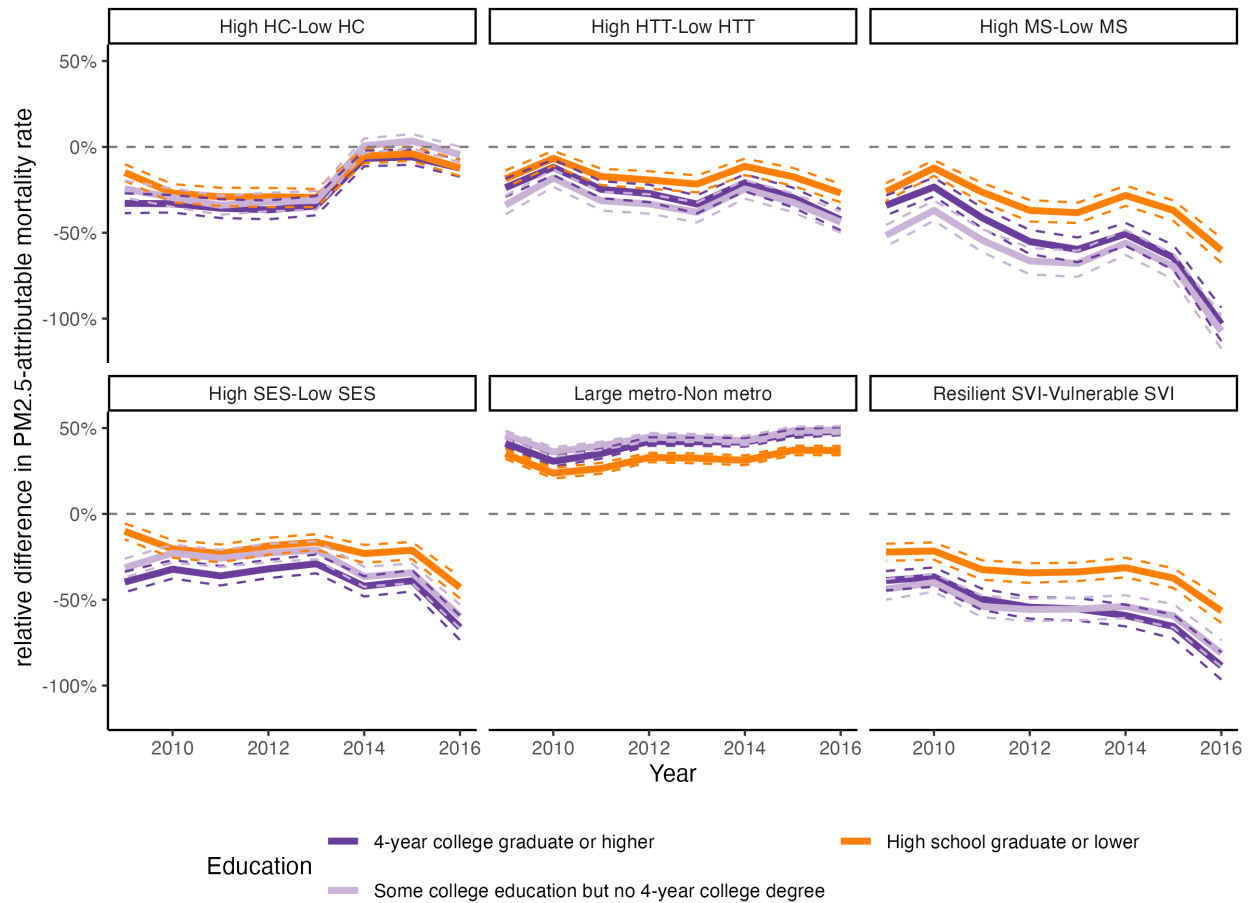
The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.

Abbreviations: NH=Non-Hispanic, MS = minority status.



Supplement Fig. 13. Age-adjusted PM2.5-attributable mortality rate and all-cause mortality rate for each education level stratified by housing type and transportation.

The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.
Abbreviations: NH=Non-Hispanic, HTT = housing type and transportation.

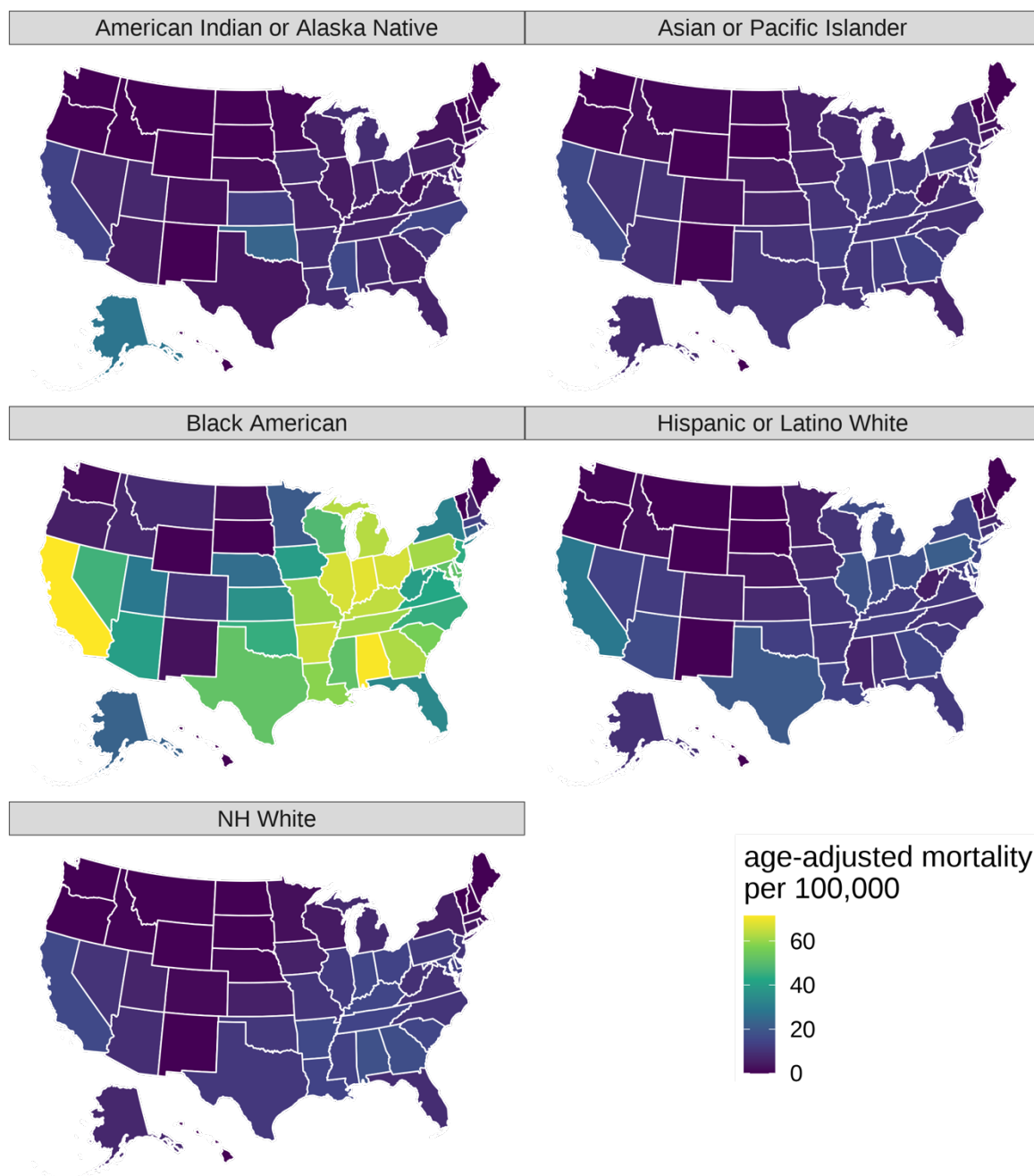


Supplement Fig. 14. Relative difference in PM_{2.5}-attributable mortality rate for each educational attainment group between different sociodemographic groups.

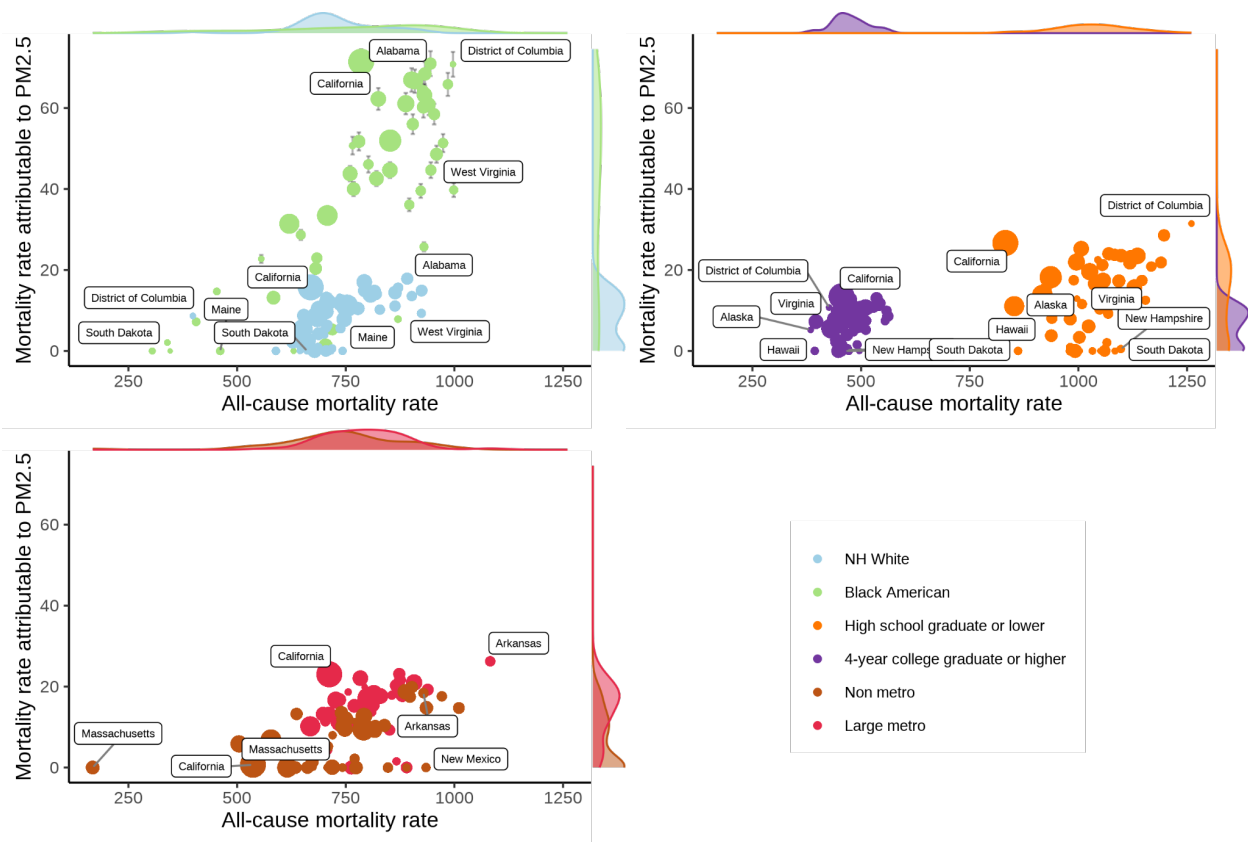
The relative difference is calculated as $(\text{PM}_{2.5} \text{ attributable mortality}_1 - \text{PM}_{2.5} \text{ attributable mortality}_2) / \text{PM}_{2.5} \text{ attributable mortality}_1$. For example, if High HTT = 20 and Low HTT = 36, then the relative difference is $(20 - 36) / 20 = -80\%$.

The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.

Abbreviations: SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index.



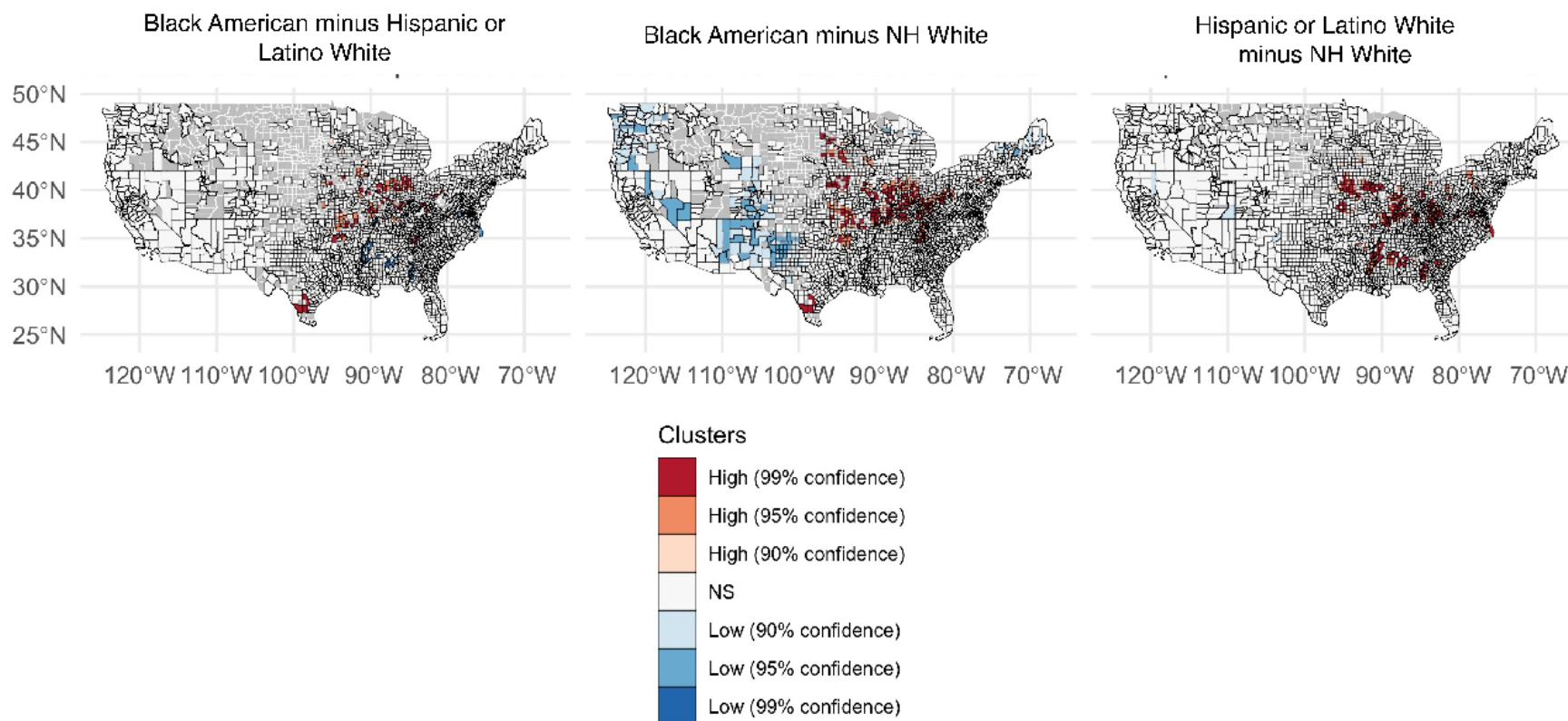
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Abbreviations: NH=Non-Hispanic.



Supplement Fig. 16. Age-adjusted mortality per 100,000 from all causes and attributable to PM2.5 (among those aged 25+ years) in the 50 US states and the District of Columbia in 2016 for the racial/ethnic groups "Black American" and "NH White", low and high educational attainment, and rurality levels "Non- metropolitan" and "large metropolitan".

The icon area for states is proportional to the state's population size. The most extreme points are labeled. Shaded areas are marginal kernel density estimates. The solid points depict mean estimates. Error bars denote 95% confidence intervals for the mortality rate attributable to PM2.5.

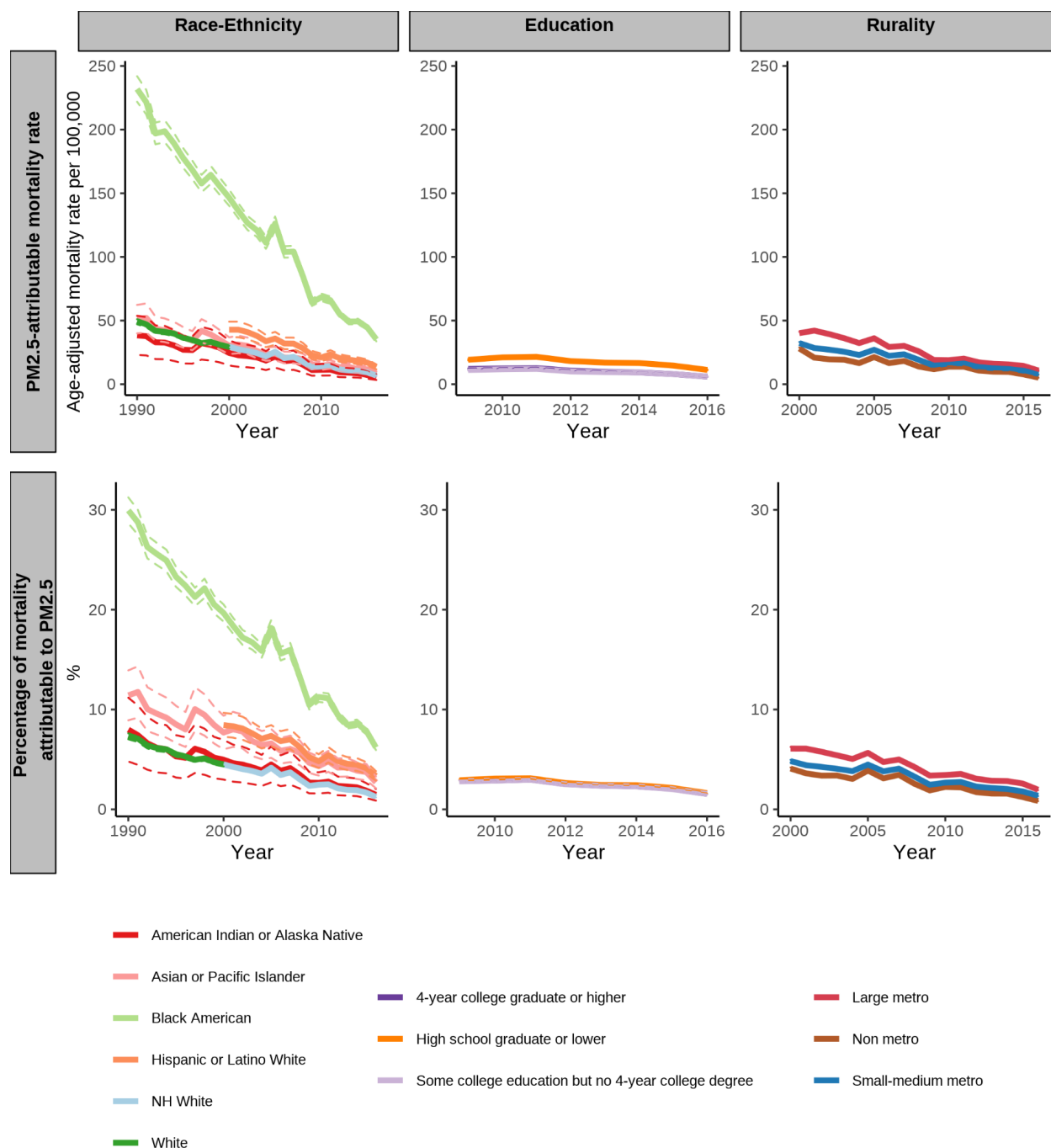
Abbreviations: NH=Non-Hispanic, metro = metropolitan.



Supplement Fig. 17. County-level spatial clusters with high (red colors) and low (blue colors) differences in the age-adjusted PM_{2.5}-attributable mortality rate between racial/ethnic groups.

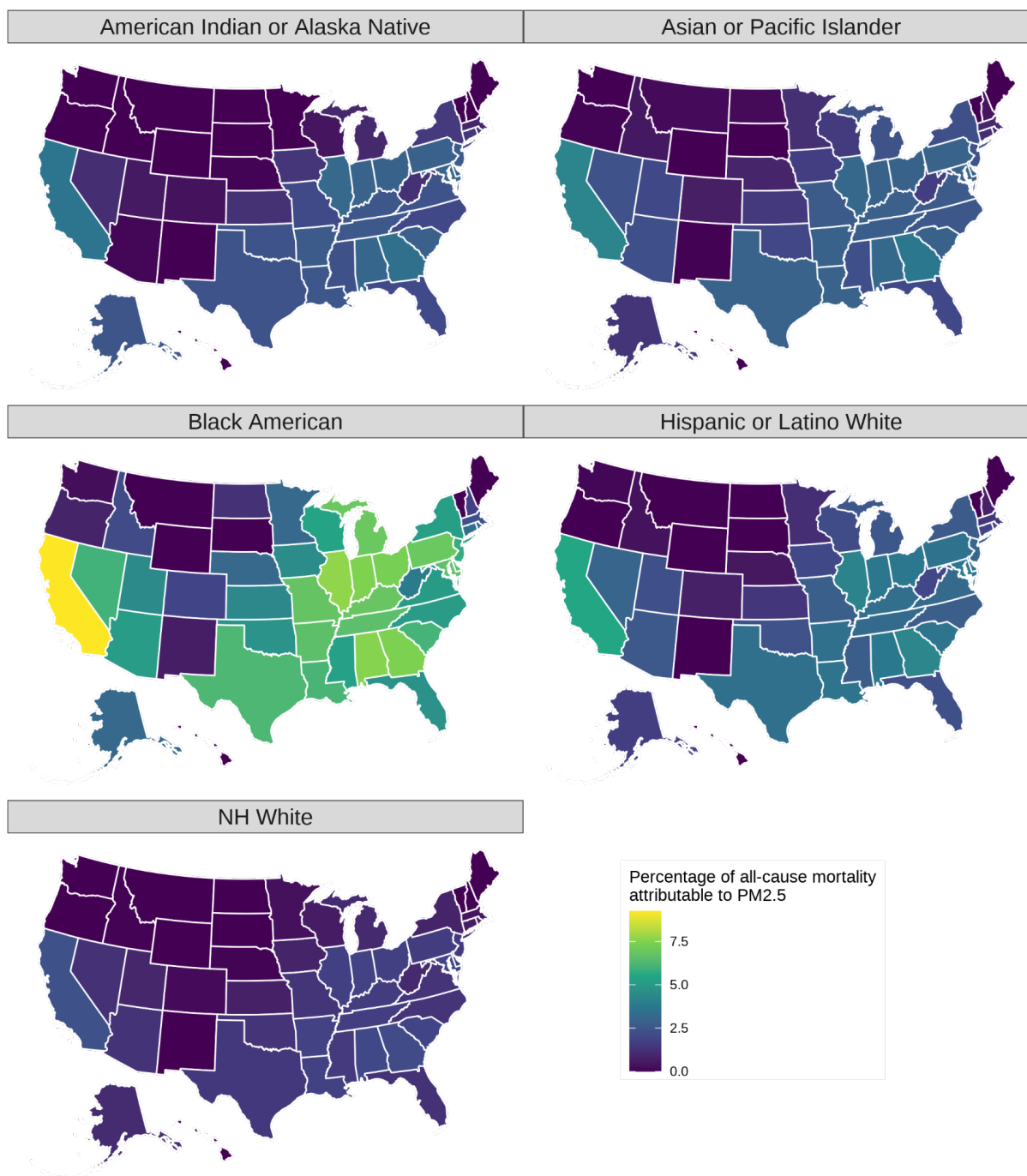
These maps were created for the (unweighted) mean across the period 2000 to 2016. Clusters were estimated with Local Spatial Autocorrelation as Local Getis-Ord Gi*. See 'Spatial analyses' in Materials and Methods for details.

Abbreviations: NH=Non-Hispanic.

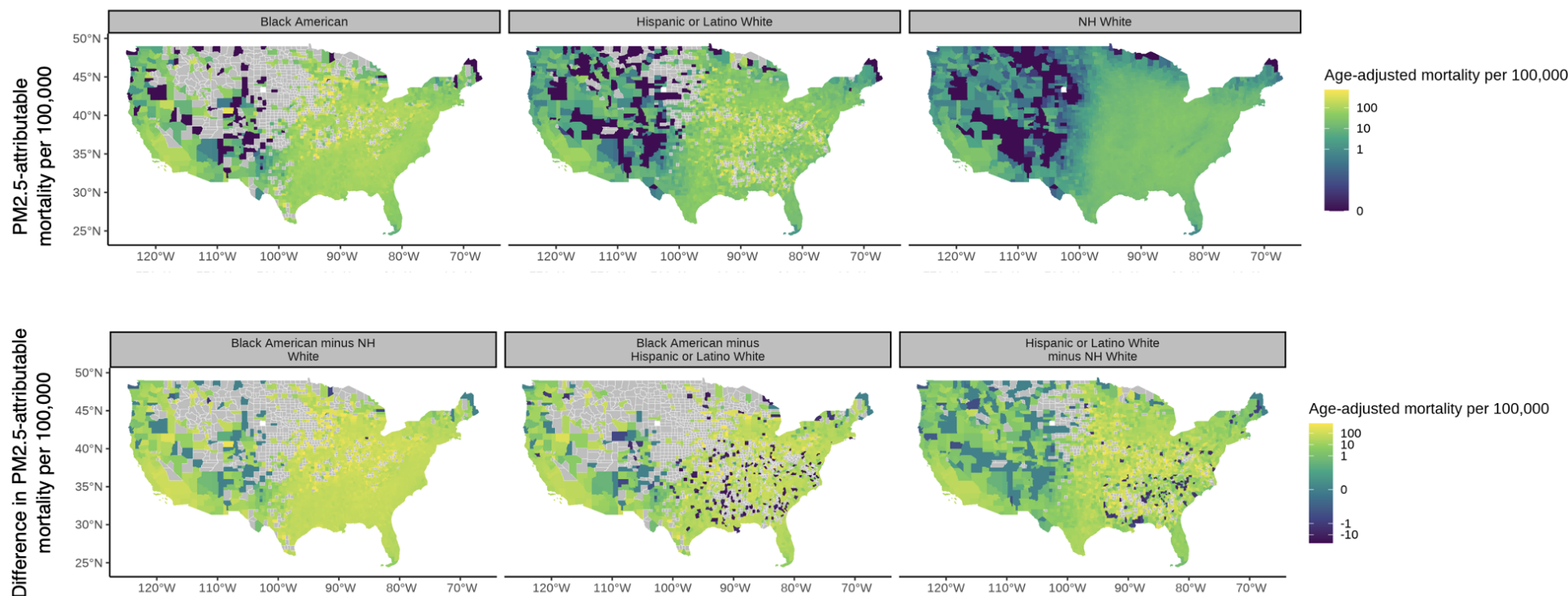


Supplement Fig. 18. Age-adjusted PM_{2.5}-attributable mortality rate by racial/ethnic group, education level, and rurality level for the age group 65+.

The first row shows the age-adjusted mortality rate that we estimate is attributable to PM_{2.5}. The second row shows the percentage of all-cause mortality that we estimate is attributable to PM_{2.5}. The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals. The dashed lines depict 95% confidence intervals. 95% confidence intervals for rurality are too narrow to be visible. Abbreviations: NH=Non-Hispanic.



Supplement Fig. 19. Percentage of the age-adjusted all-cause mortality rate that was attributable to PM_{2.5} in the year 2016, by state and racial/ethnic group for the age group 65+.
Abbreviations: NH=Non-Hispanic.

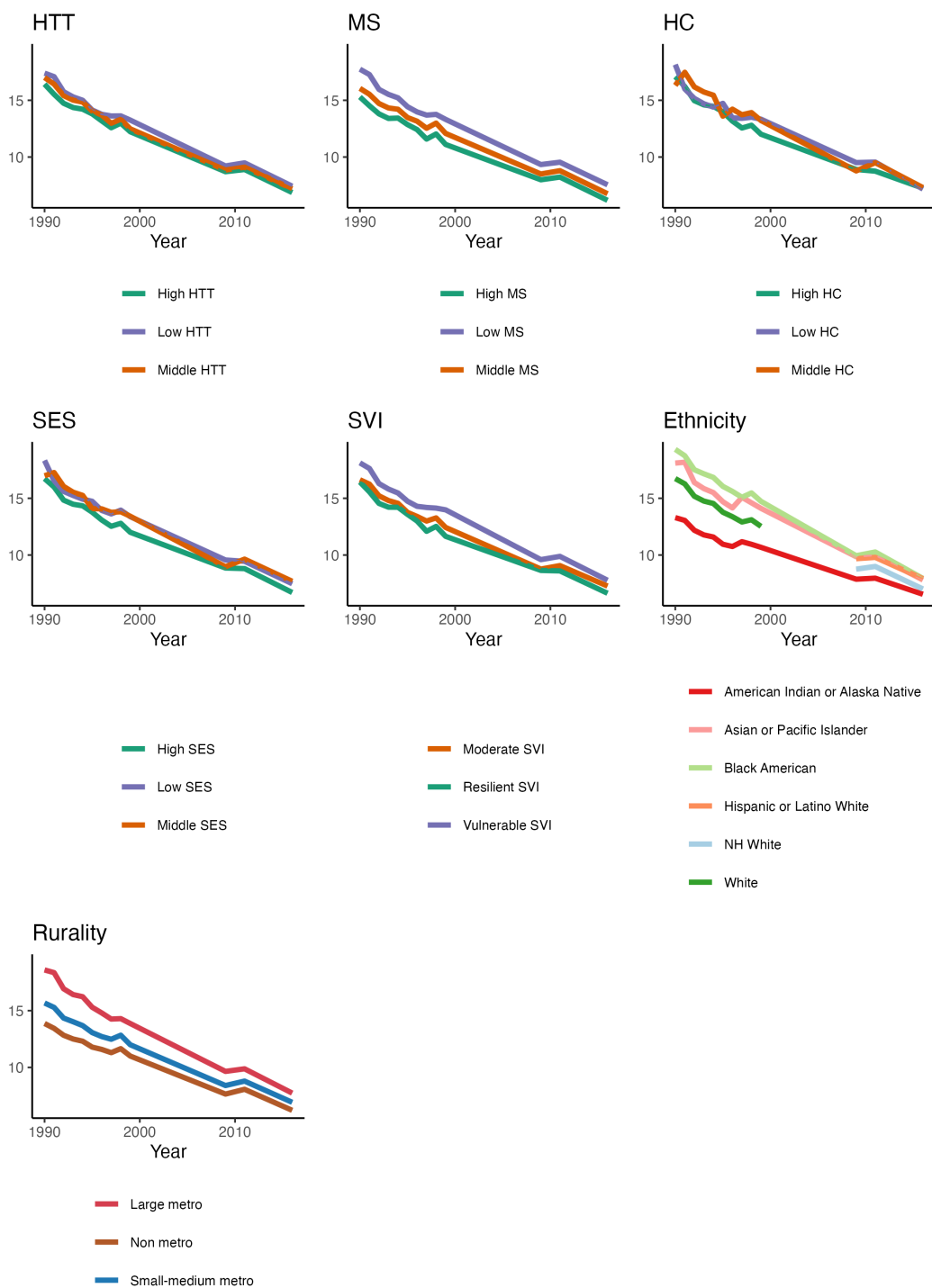


Supplement Fig. 20. Differences in the age-adjusted PM_{2.5}-attributable mortality rate between the racial/ethnic groups at the county level for the period 2000 to 2016 for the age group 65+ years.

The first row is the PM_{2.5}-attributable mortality per 100,000 for each racial/ethnic group.

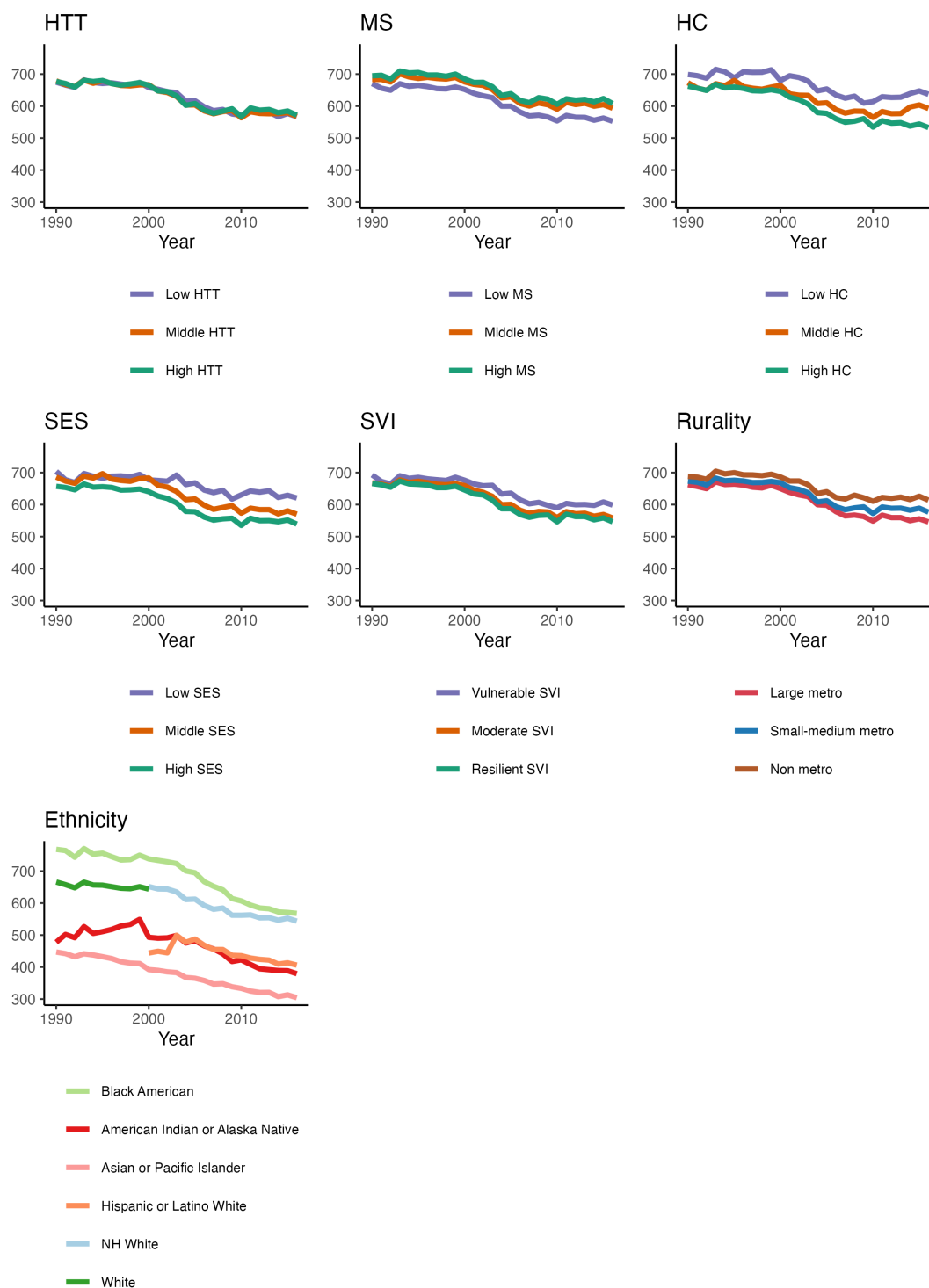
The second row is the absolute difference in PM_{2.5}-attributable mortality per 100,000 between racial/ethnic groups.

Abbreviations: NH=Non-Hispanic



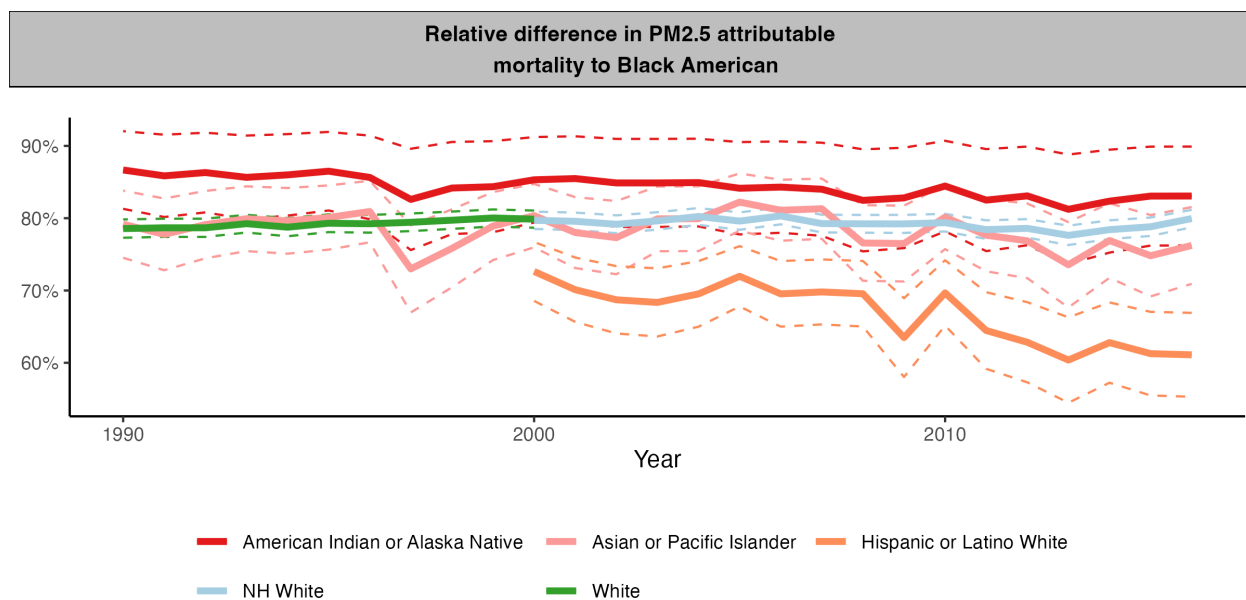
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Abbreviations: NH=Non-Hispanic, SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index.



Supplement Fig. 22. Age-adjusted mortality per 100,000 from all causes by racial/ethnic group, education attainment level, and rurality level for the age-group 65+ years.

Abbreviations: NH=Non-Hispanic, SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index.

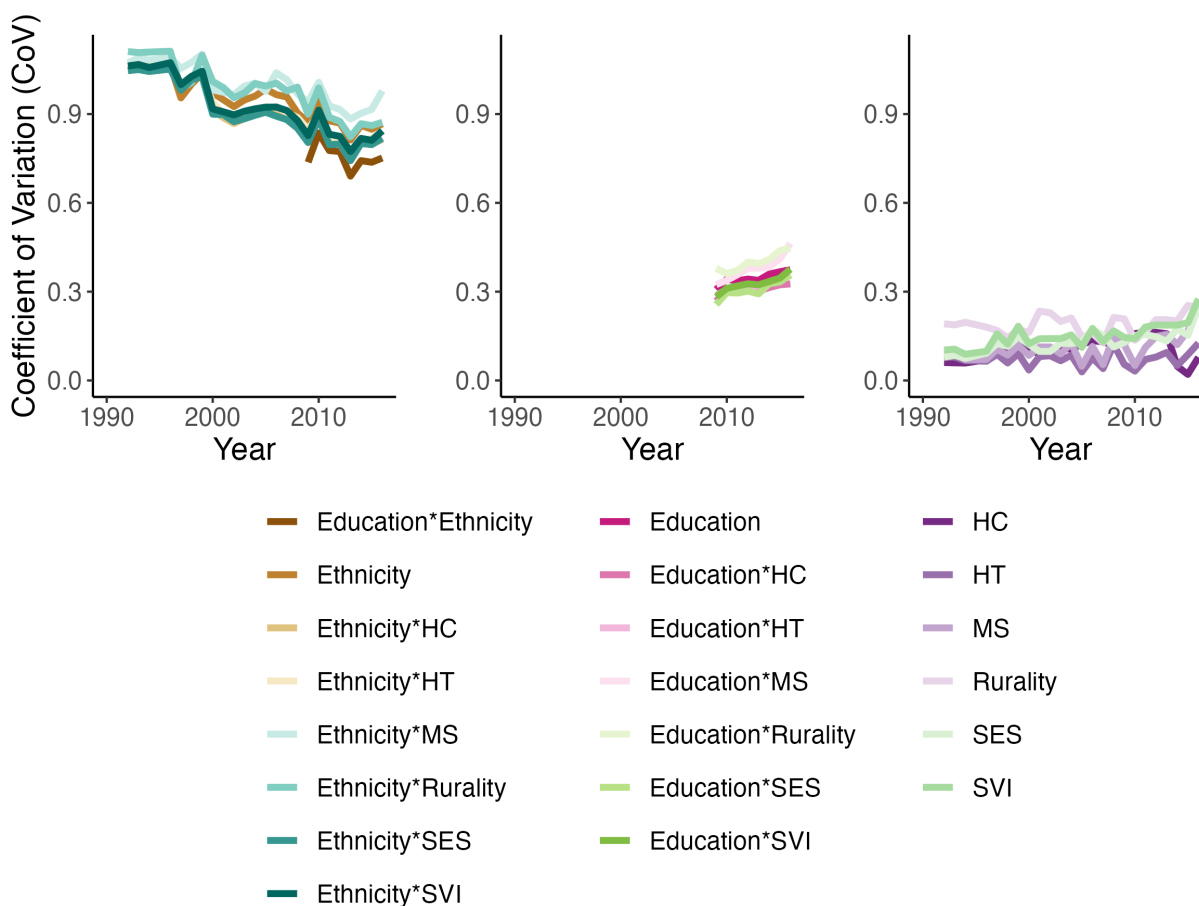


Supplement Fig. 23. Percent at which the PM_{2.5}-attributable mortality rate per 100,000 is lower for each racial/ethnic group relative to Black Americans for the age group 65+ years.

This figure is for the age group 65+ years and spans the period 1990 to 2016.

Abbreviations: NH=Non-Hispanic.

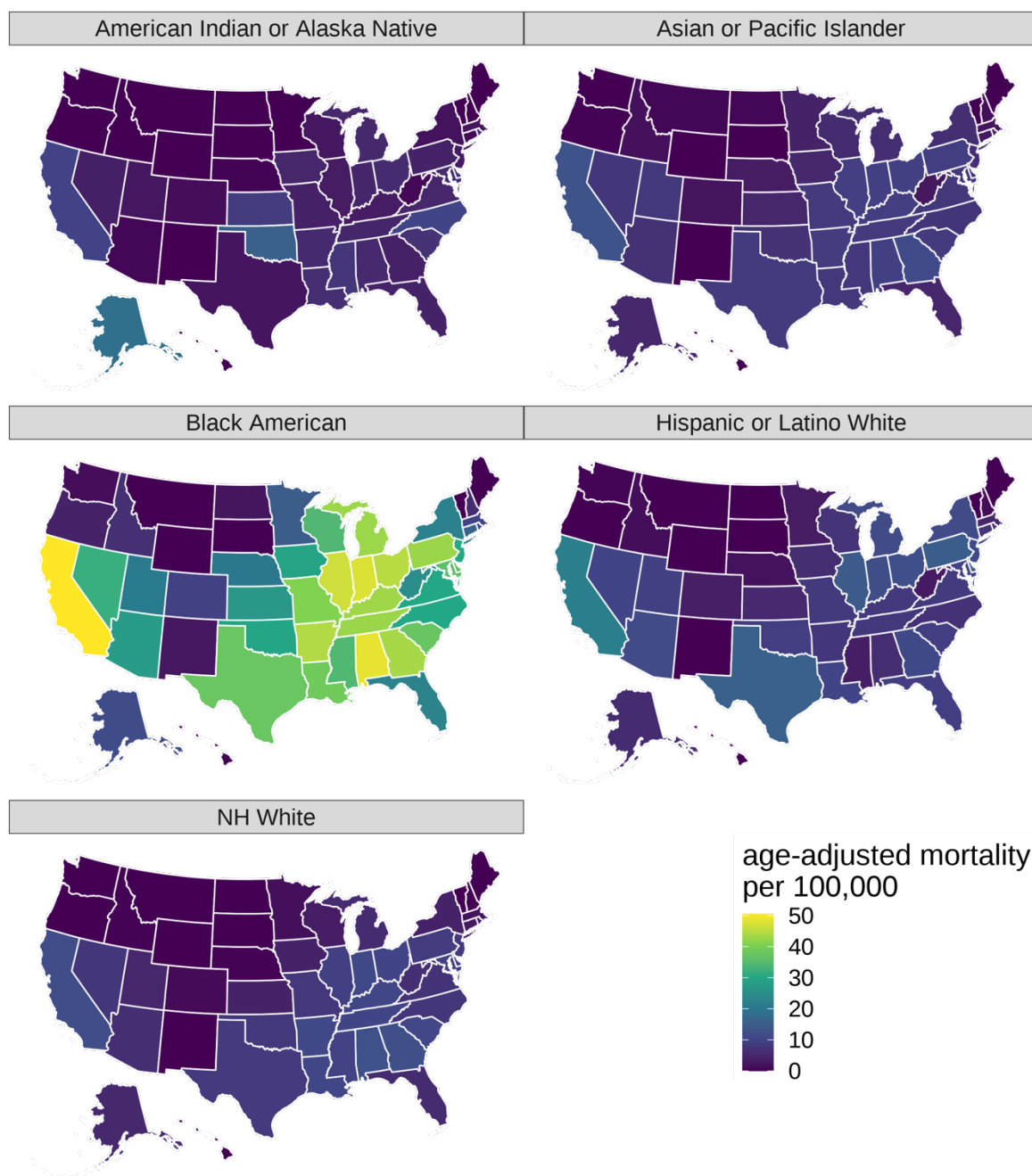
The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.



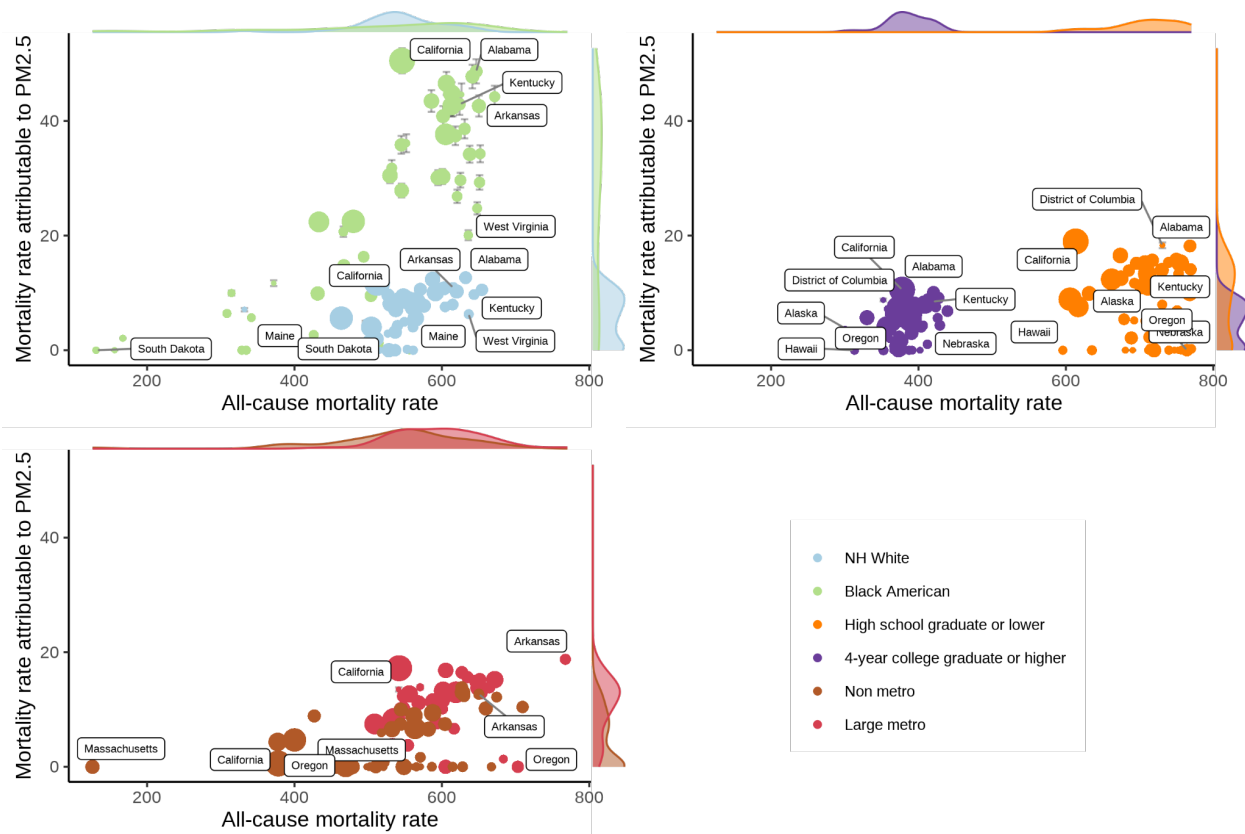
Supplement Fig. 25. Coefficient of Variation (CoV) of age-adjusted all-cause mortality attributable to PM_{2.5} when stratifying by different sociodemographic groups for the age group 65+ years.

The line for “race-ethnicity*education” corresponds to the CoV between the 15 racial/ethnic and education group combinations available. The CoV is the standard deviation of the age-adjusted PM_{2.5}-attributable mortality rate divided by the mean age-adjusted PM_{2.5}-attributable mortality rate.

Abbreviations: NH=Non-Hispanic, SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index.



Supplement Fig. 26. Age-adjusted PM_{2.5}-attributable mortality rate for the age group 65+ years in the year 2016, by state and racial/ethnic group.
Abbreviations: NH=Non-Hispanic.

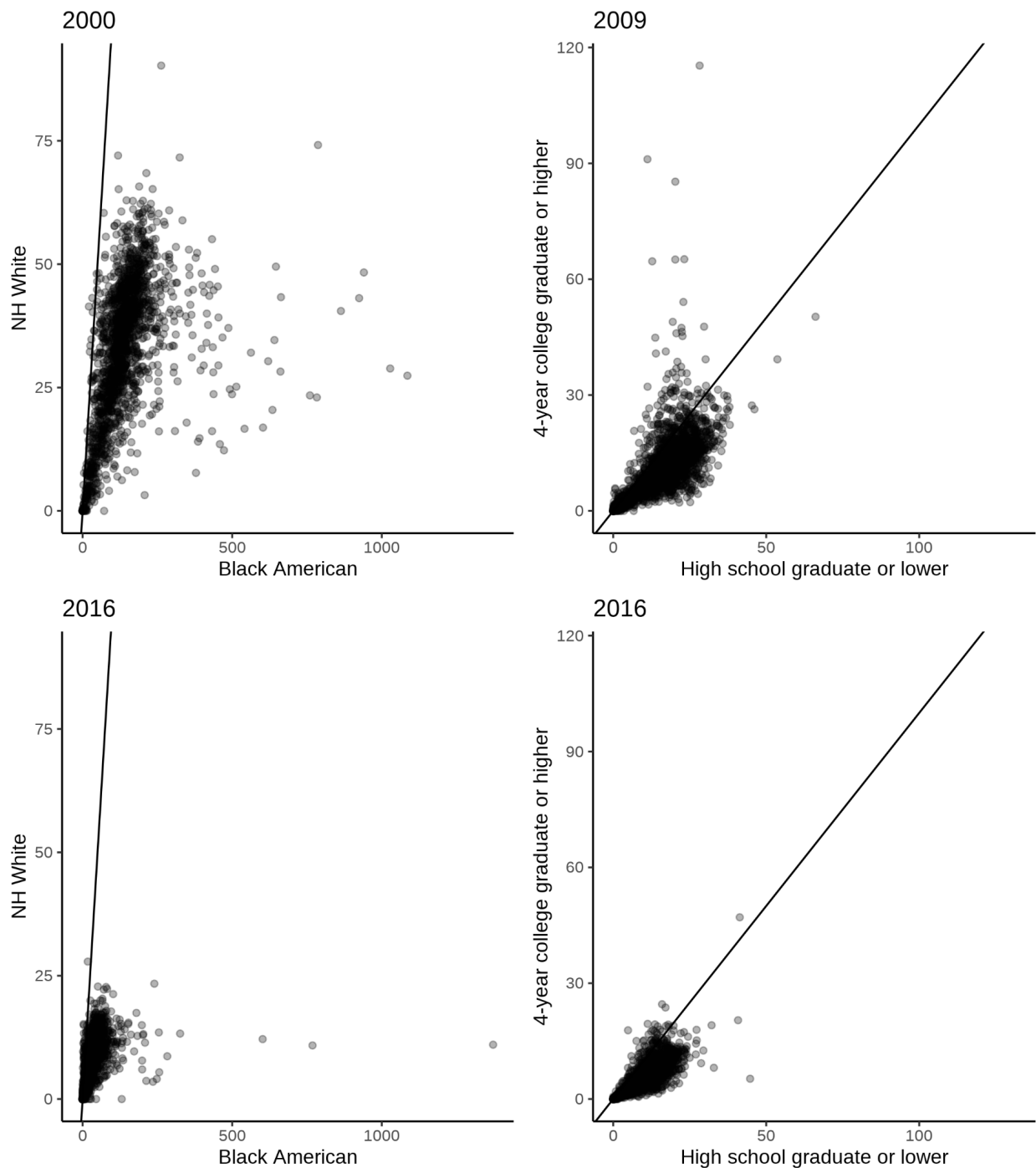


Supplement Fig. 27. Age-adjusted mortality per 100,000 from all causes and attributable to PM_{2.5} (among those aged 65+ years) in the 50 US states and the District of Columbia in 2016 for the racial/ethnic groups “Black American” and “NH White”, low and high educational attainment, and rurality levels “Non-metropolitan” and “large metropolitan”

The icon area for states is proportional to the state’s population size. The most extreme points are labeled. Shaded areas are marginal kernel density estimates. The solid points depict mean estimates. The dashed lines depict 95% confidence intervals.

Error bars denote 95% confidence intervals for the mortality rate attributable to PM_{2.5}.

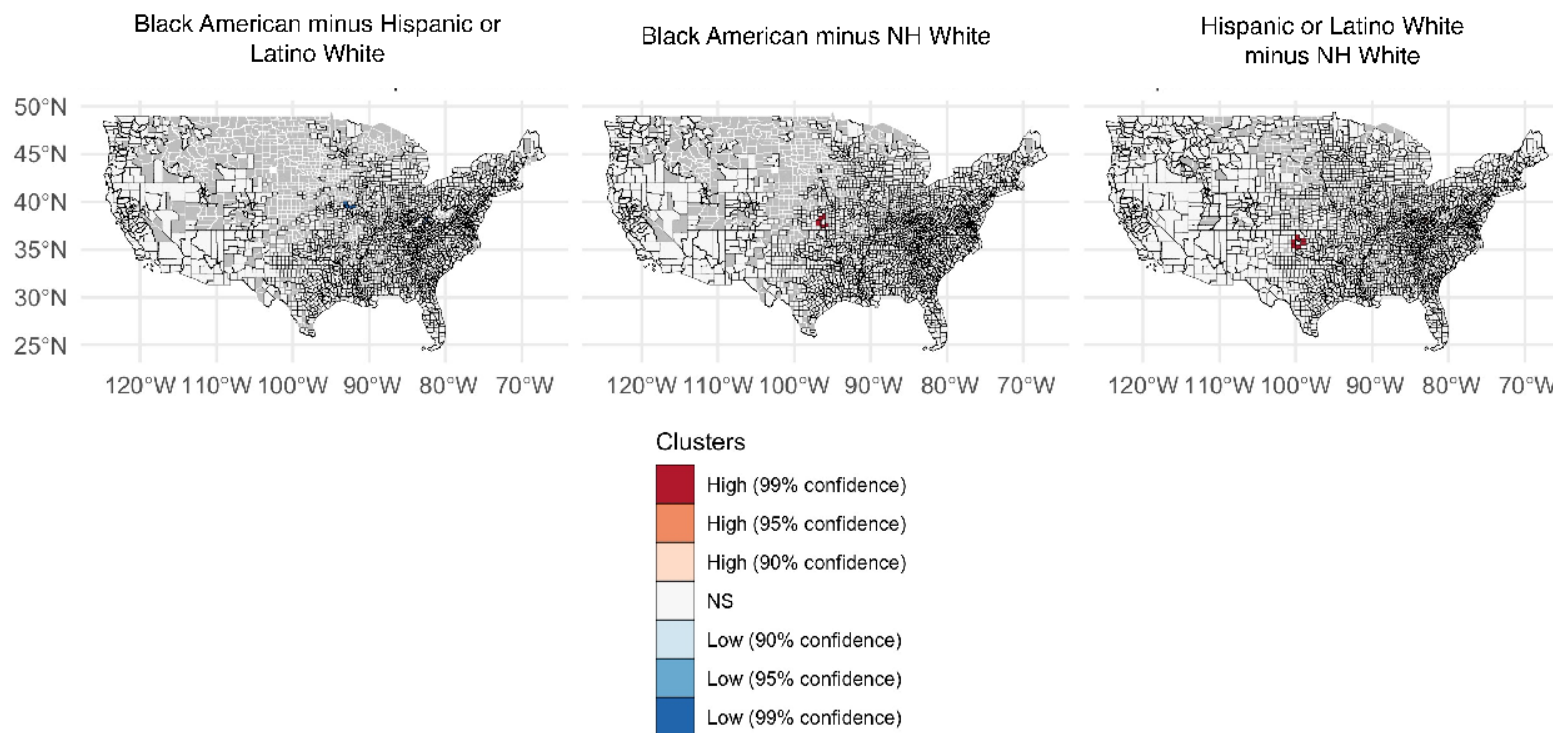
Abbreviations: NH=Non-Hispanic, metro= metropolitan.



Supplement Fig. 28. County-level scatter plot of the age-adjusted mortality per 100,000 attributable to $PM_{2.5}$ for selected racial/ethnic groups and education level comparisons for age group 65+ years.

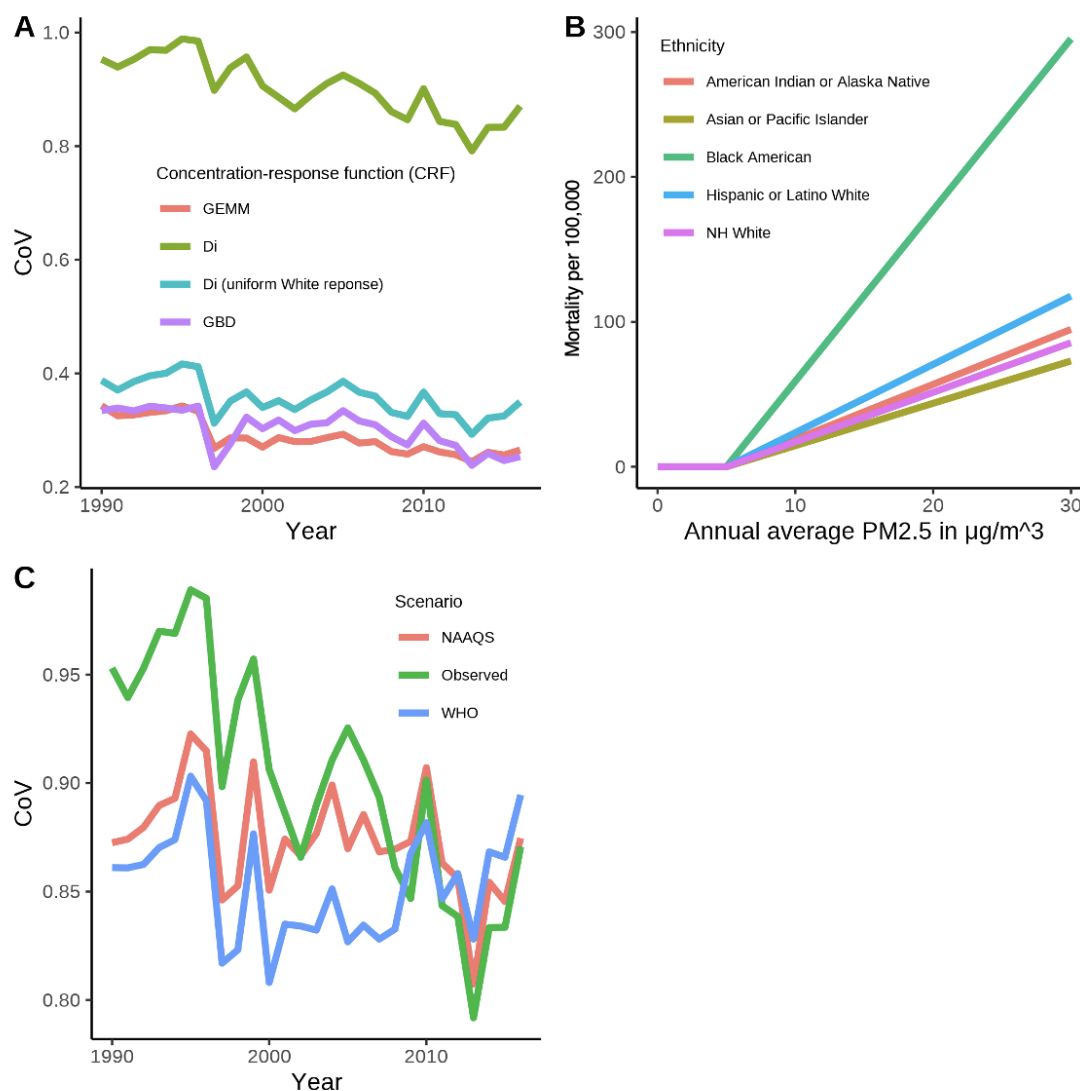
These estimates are for the population aged 65+ years in the USA. Each point represents one county. Points on the straight line imply that the age-adjusted $PM_{2.5}$ -attributable mortality rate was the same for the group denoted on the x-axis as for the group denoted on the y-axis. Points below the straight line imply that the age-adjusted $PM_{2.5}$ -attributable mortality rate for the group on the x-axis was higher than for the group on the y-axis.

Abbreviations: NH=Non-Hispanic.



Supplement Fig. 29. County-level spatial clusters with high (red colors) and low (blue colors) differences in the age-adjusted PM_{2.5}-attributable mortality rate between racial/ethnic groups for the age group 65+ years.

These maps were created for the (unweighted) mean across the period 2000 to 2016. Clusters were estimated with Local Spatial Autocorrelation as Local Getis-Ord Gi* (see “Spatial analyses” in the Materials and Methods section). Abbreviations: NH=Non-Hispanic.

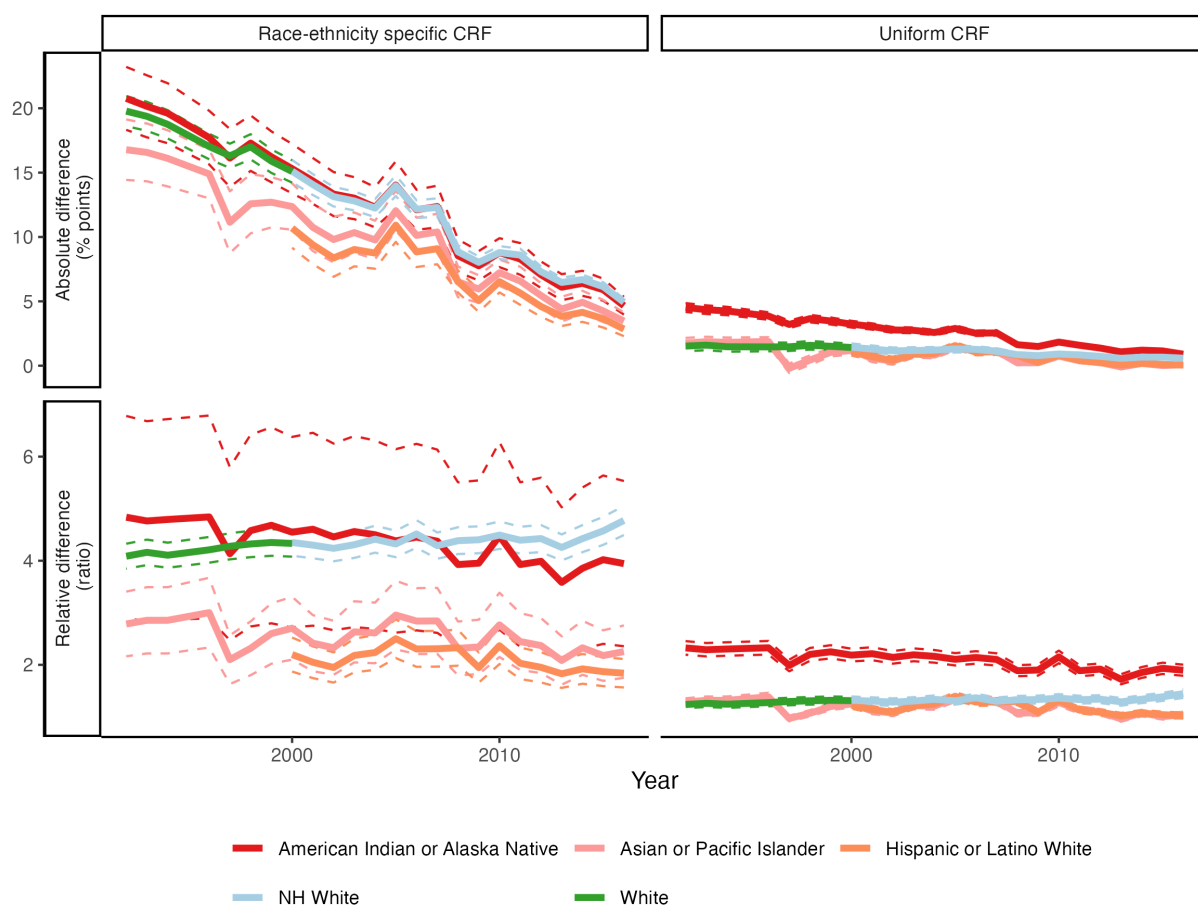


Supplement Fig. 30. Analyses to examine the importance of using race-ethnicity specific CRFs for the age group 65+ years.

(A) is the Coefficient of Variation (CoV) of age-adjusted PM_{2.5}-attributable mortality per 100,000 across raceethnicities for different CRFs. The CoV is the standard deviation of the age-adjusted PM_{2.5}-attributable mortality rate divided by the mean age-adjusted PM_{2.5}-attributable mortality rate.

(B) is the age-adjusted mortality per 100,000 attributable to PM_{2.5} in the USA by racial/ethnic group using the raceethnicity-specific CRF by Di et al., but assuming the same exposure (the population-weighted mean across the US population) to PM_{2.5} for all racial/ethnic groups.

(C) is the Coefficient of Variation (CoV) of the age-adjusted PM_{2.5}-attributable mortality rate for different stylized scenarios: the real observed PM_{2.5} exposure ("observed"), as well as a scenario each where all counties are compliant with the National Ambient Air Quality standards set by the US Environmental Protection Agency (EPA) at 12µg/ m³ ("NAAQS"), and the guideline set by the World Health Organization (WHO) at 10µg/m³ ("WHO"). Abbreviations: CRF=concentration response function; NH=Non-Hispanic.

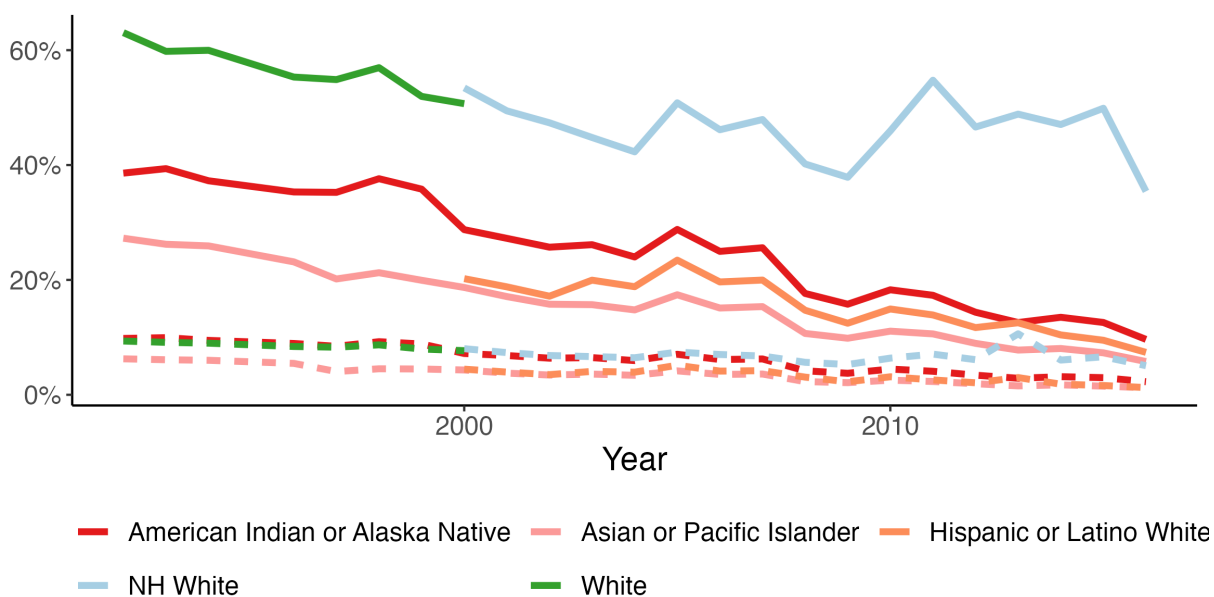


Supplement Fig. 31. Differences in the proportion of all-cause mortality that was attributable to PM_{2.5} for the age group 65+ years between Black Americans and other racial/ethnic groups.

The first row is the *absolute difference* (in percentage points) of the proportion of the age-adjusted all-cause mortality that was attributable to PM_{2.5} between Black Americans and each racial/ethnic group. Positive values indicate that Black Americans had a higher proportion of all-cause mortality attributable to PM_{2.5}. The second row is the *ratio* (i.e., a measure of the relative difference) of the proportion of the age-adjusted all-cause mortality that was attributable to PM_{2.5} for Black Americans divided by the proportion of the age-adjusted all-cause mortality that was attributable to PM_{2.5} for each racial/ethnic group. The first column assumes the race-ethnicity-specific CRF from Di et al.. The second column assumes a uniform CRF for all racial/ethnic groups by applying the CRF for “NH White” from Di et al. to all racial/ethnic groups.

The solid lines depict mean estimates. The dashed lines depict 95% confidence intervals.

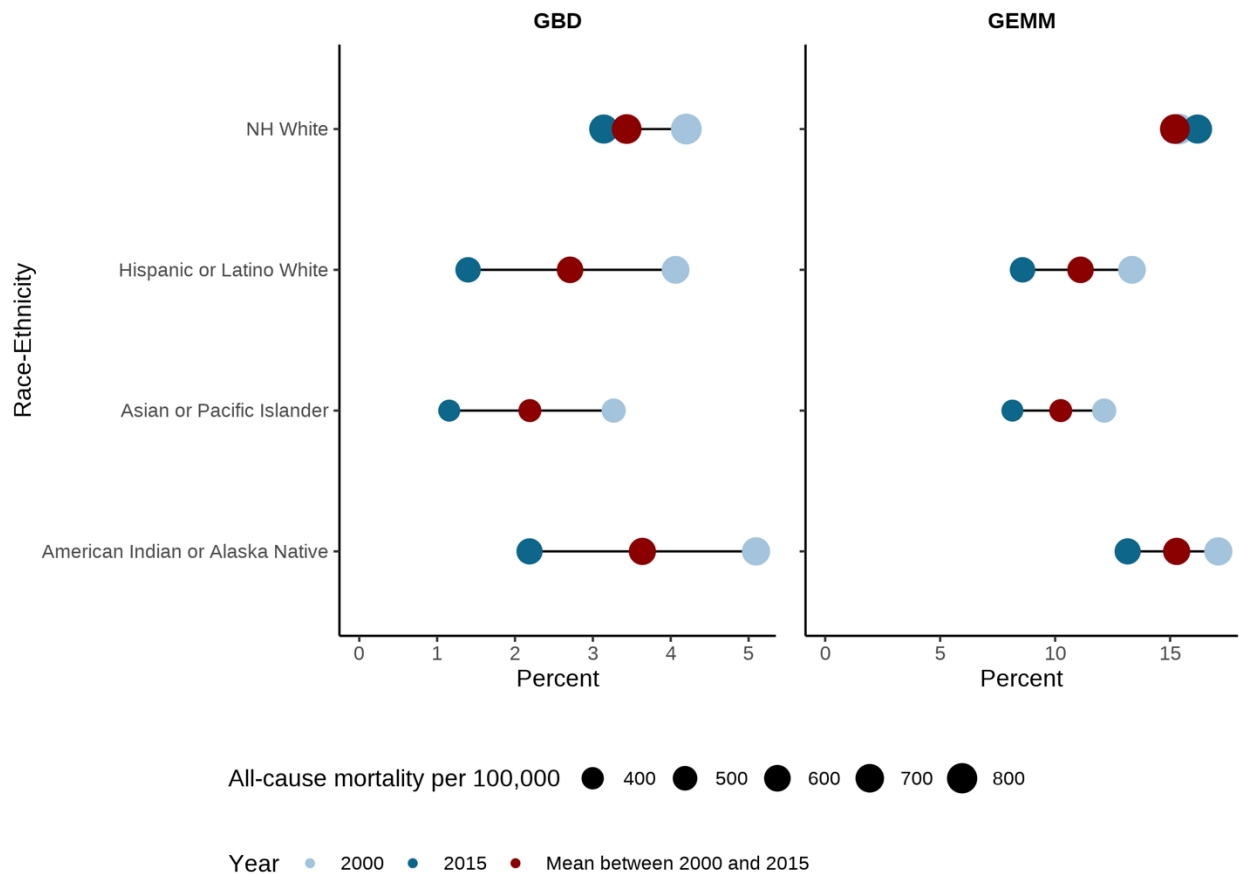
Abbreviations: CRF=concentration response function; NH=Non-Hispanic.



Supplement Fig. 32. Percent of the difference in the age-adjusted mortality rate between each race-ethnicity and “Black American” that is attributable to $PM_{2.5}$, using either race-ethnicity-specific CRFs (solid lines) or a uniform CRF (dashed lines).

The solid lines are the results calculated using race-ethnicity-specific CRFs from Di et al.. The dashed lines are the results calculated when applying the CRF in Di et al. for “NH White” to all race-ethnicities.

Abbreviations: CRF=Concentration-response function; NH=Non-Hispanic.

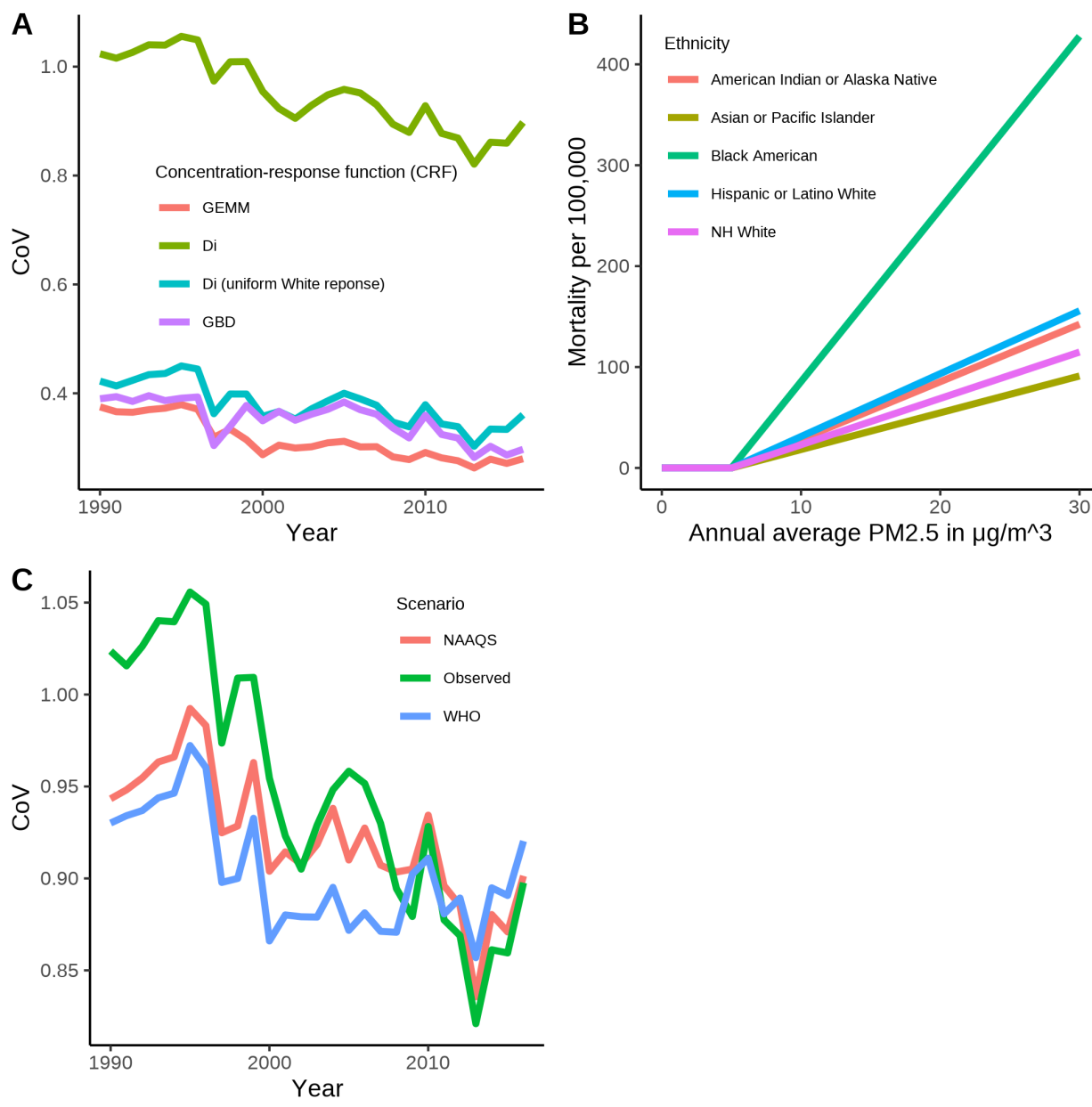


Supplement Fig. Supplement Fig. 33. Extent to which the difference in the age-adjusted mortality rate between each racial/ethnic group and Black Americans can be attributed to PM_{2.5}.

Of the racial/ethnic groups considered in this study, Black Americans have both the highest all-cause mortality rate and highest PM_{2.5}-attributable mortality rate. Both columns are the percent of the difference in all-cause mortality between each race-ethnicity and Black Americans that can be attributed to PM_{2.5} exposure. The left column is GBD, the right column is GEMM.

Dark blue dots denote 2015 and light blue dots denote 2000. Red dots denote the unweighted mean from 2000 to 2015. The dot sizes are proportional to the age-adjusted all-cause mortality rate that is attributable to PM_{2.5}.

Abbreviations: NH=Non-Hispanic



Supplement Fig. 34. Analyses to examine the importance of using race-ethnicity specific CRFs for the age group 25+ years.

(A) is the Coefficient of Variation (CoV) of age-adjusted PM_{2.5}-attributable mortality per 100,000 across racial/ethnic groups for different CRFs. The CoV is the standard deviation of the age-adjusted PM_{2.5}-attributable mortality rate divided by the mean age-adjusted PM_{2.5}-attributable mortality rate.

(B) is the age-adjusted mortality per 100,000 attributable to PM_{2.5} in the USA by racial/ethnic group using the race-ethnicity-specific CRF by Di et al., but assuming the same exposure (the population-weighted mean across the US population) to PM_{2.5} for all racial/ethnic groups.

(C) is the Coefficient of Variation (CoV) of the age-adjusted PM_{2.5}-attributable mortality rate for different stylized scenarios: the real observed PM_{2.5} exposure (“observed”), as well as a scenario each where all counties are compliant with the National Ambient Air Quality standards set by the US Environmental Protection Agency (EPA) at $12\mu\text{g}/\text{m}^3$ (“NAAQS”), and the guideline set by the World Health Organization (WHO) at $10\mu\text{g}/\text{m}^3$ (“WHO”). Abbreviations: NH=Non-Hispanic, CoV = Coefficient of Variation; CRF=Concentration-response function.

Year(s)	Population subgroup	Data source	Table(s)	Age groups
1990	Racial/ethnic group	IPUMS	NP10	25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+
1991-1999	Racial/ethnic group	Interpolation of 1990 and 2000 using Longitudinal Tract Database	-	25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+
2000	Racial/ethnic group	U.S. Census Bureau, 2000 Decennial Census, Summary File 1	P012A, P012B, P012C, P012D, P012E, P012I	25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+
2001-2008	Racial/ethnic group	Interpolation of 2000 and 2010 using Longitudinal Tract Database	-	25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+
2009, 2011-2016	Racial/ethnic group	U.S. Census Bureau, American Community Survey, 5-year Estimates	B01001A, B01001B, B01001C, B01001D, B01001E, B01001H	25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+
2009-2016	Education	U.S. Census Bureau, American Community Survey, 5-year Estimates	B15001	25-34, 35-44, 45-64, 65+

2009-2016	Combinations of education and racial/ethnic group	U.S. Census Bureau, American Community Survey, 5-year Estimates	C15002A, C15002B, C15002C, C15002D, C15002E, C15002H	Single age group for 25 years and above
2010	Racial/ethnic group	U.S. Census Bureau, 2010 Decennial Census, Summary File 1	PCT12A, PCT12B, PCT12C, PCT12D, PCT12E, PCT12I	25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+

Supplementary Table 1. Data sources for the population counts used in the estimation of population-weighted mean PM_{2.5} exposure.

All these data sources were at the census-tract level.

Data from the U.S. Census Bureau is available at <https://data.census.gov/cedsci/>.

Data from IPUMS is available at <https://data2.nhgis.org/main>.

Geographic level(s)	Population sub-group	Year(s)	Source for population count	Age categories
County	Racial/ethnic group	1990	IPUMS	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
County	Racial/ethnic group	1991-1999	Interpolation of 1990 and 2000 using Longitudinal Tract Database	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
County	Racial/ethnic group	2000	U.S. Census Bureau, 2000 Decennial Census, Summary File 1	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
County	Racial/ethnic group	2001-2008	Interpolation of 2000 and 2010 using Longitudinal Tract Database	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
County	Racial/ethnic group	2009, 2011-2016	U.S. Census Bureau, American Community Survey, 5-year Estimates	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
County	Racial/ethnic group	2010	U.S. Census Bureau, 2010 Decennial Census, Summary File 1	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Racial/ethnic group	1990-2016	Bridged-race resident population estimates	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State, County	Education	2009-2016	U.S. Census Bureau, American Community Survey, 5-year Estimates	25-34, 35-44, 45-64, 65+
National, State	Combinations of racial/ethnic group with rurality, SES,	1990	IPUMS	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+

	HC, MS, HTT, SVI			
National, State	Combinations of racial/ethnic group with rurality, SES, HC, MS, HTT, SVI	1991-1999	Interpolation of 1990 and 2000 using Longitudinal Tract Database	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Combinations of racial/ethnic group with rurality, SES, HC, MS, HTT, SVI	2000	U.S. Census Bureau, 2000 Decennial Census, Summary File 1	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Combinations of race-ethnicity with rurality, SES, HC, MS, HTT, SVI	2001-2008	Interpolation of 2000 and 2010 using Longitudinal Tract Database	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Combinations of racial/ethnic group with rurality, SES, HC, MS, HTT, SVI	2009, 2011-2016	U.S. Census Bureau, American Community Survey, 5-year Estimates	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Combinations of racial/ethnic group with rurality, SES, HC, MS, HTT, SVI	2010	U.S. Census Bureau, 2010 Decennial Census, Summary File 1	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Rurality, SES, HC, MS, HTT, SVI	1990	IPUMS	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Rurality, SES, HC, MS, HTT, SVI	1991-1999	Interpolation of 1990 and 2000 using Longitudinal Tract Database	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Rurality, SES, HC, MS, HTT, SVI	2000	U.S. Census Bureau, 2000 Decennial Census, Summary File 1	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+

National, State	Rurality, SES, HC, MS, HTT, SVI	2001-2008	Interpolation of 2000 and 2010 using Longitudinal Tract Database	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National, State	Rurality, SES, HC, MS, HTT, SVI	2009, 2011-2016	U.S. Census Bureau, American Community Survey, 5-year Estimates	25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+
National	Combinations of education and racial/ethnic group	2009-2016	U.S. Census Bureau, Population Survey, Annual Social and Economic Supplement	25-34, 35-44, 45-54, 55-64, 65-74, 75+
National, State	Combinations of education with rurality, SES, HC, MS, HTT, SVI	2009-2016	U.S. Census Bureau, American Community Survey, 5-year Estimates	25-34, 35-44, 45-64, 65+

Supplementary Table 2. Data sources for the population counts used in the calculation of age-adjusted mortality rates.

The US 2000 standard population table, which is also used for the calculation in the National Vital Statistics Report, has the age categories 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, and 85+. Population counts that were available in more granular age categories were aggregated to these coarser categories.

Abbreviations: SES = Socioeconomic Status, HC = Household Characteristics, MS = Minority Status, HTT = Housing Type & Transportation, SVI = Social Vulnerability Index.

CRF	Name of condition	ICD-10 code
GBD	Ischemic heart disease	I20-I25.9
	Ischemic stroke	G45-G46.8, I63-I63.9, I65-I66.9, I67.2-I67.3, I67.5-I67.6, I69.3
	Intracerebral hemorrhage	I61-I62, I62.1-I62.9, I68.1-I68.2, I69.1-I69.2
	Subarachnoid hemorrhage	I60-I60.9, I62.0, I67.0-I67.1, I69.0
	Tracheal, bronchus, and lung cancer	C33-C34.9, D02.1-D02.3, D14.2-D14.3, D38.1
	Chronic obstructive pulmonary disease	J41-J44.9
	Lower respiratory infection	A48.1, A70, B97.4-B97.6, J09-J15.8, J16-J16.9, J20-J21.9, P23.0-P23.4, U04-U04.9
	Diabetes mellitus type 2	E11-E11.1, E11.3-E11.9
GEMM	Non-communicable diseases	C00-C97, D00–D48, D55-D64, D65–D89, E03-E07, E10-E16, E20-E34, E65-E88, F01-F99, G06-G98, H68-H93, I00-I99, G06-G98, H00-H61, J30-J98, K00-K92, N00-N64, N75-N98, L00-L98, M00-M99, Q00-Q99
Di et al.	All	-

Supplementary Table 3. ICD-10 codes used in each concentration-response function.

Abbreviations: CRF=concentration-response function.