Wildfire emissions disrupt black carbon and PM2.5 mortality burden trends across the continental US

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Thanks to all co-authors

Long-term mortality burden trends attributed to black carbon and $PM_{2.5}$ from wildfire emissions across the continental USA from 2000 to 2020: a deep learning modelling study

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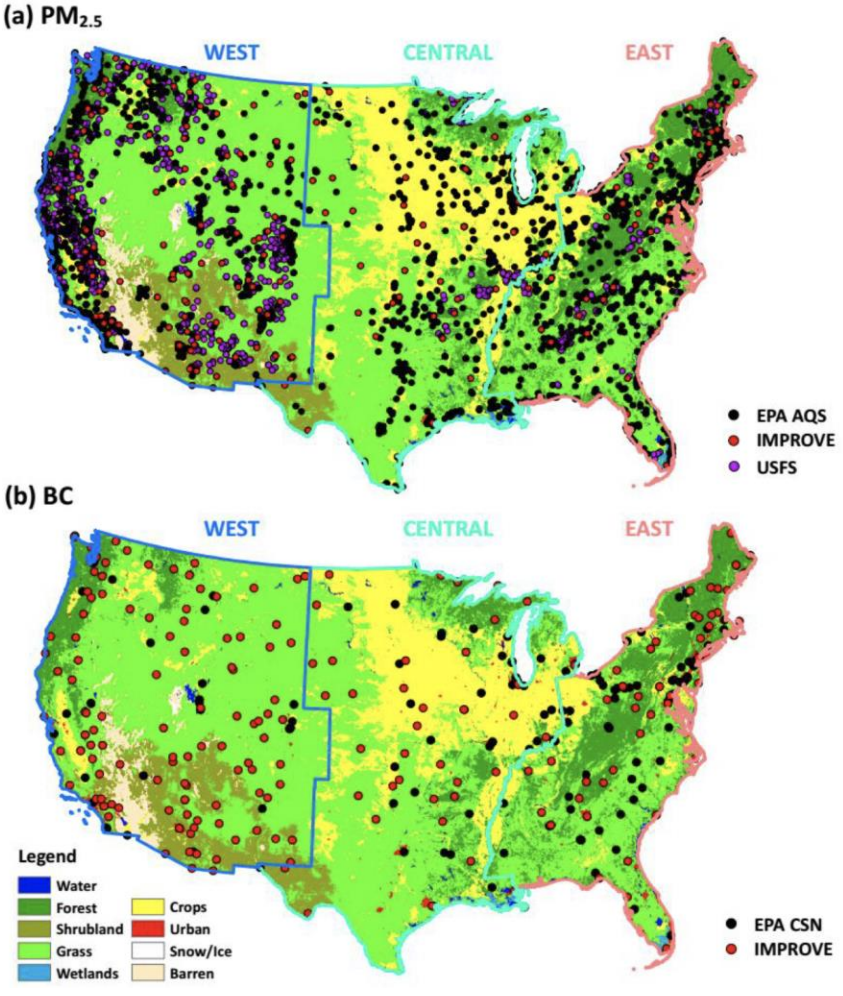
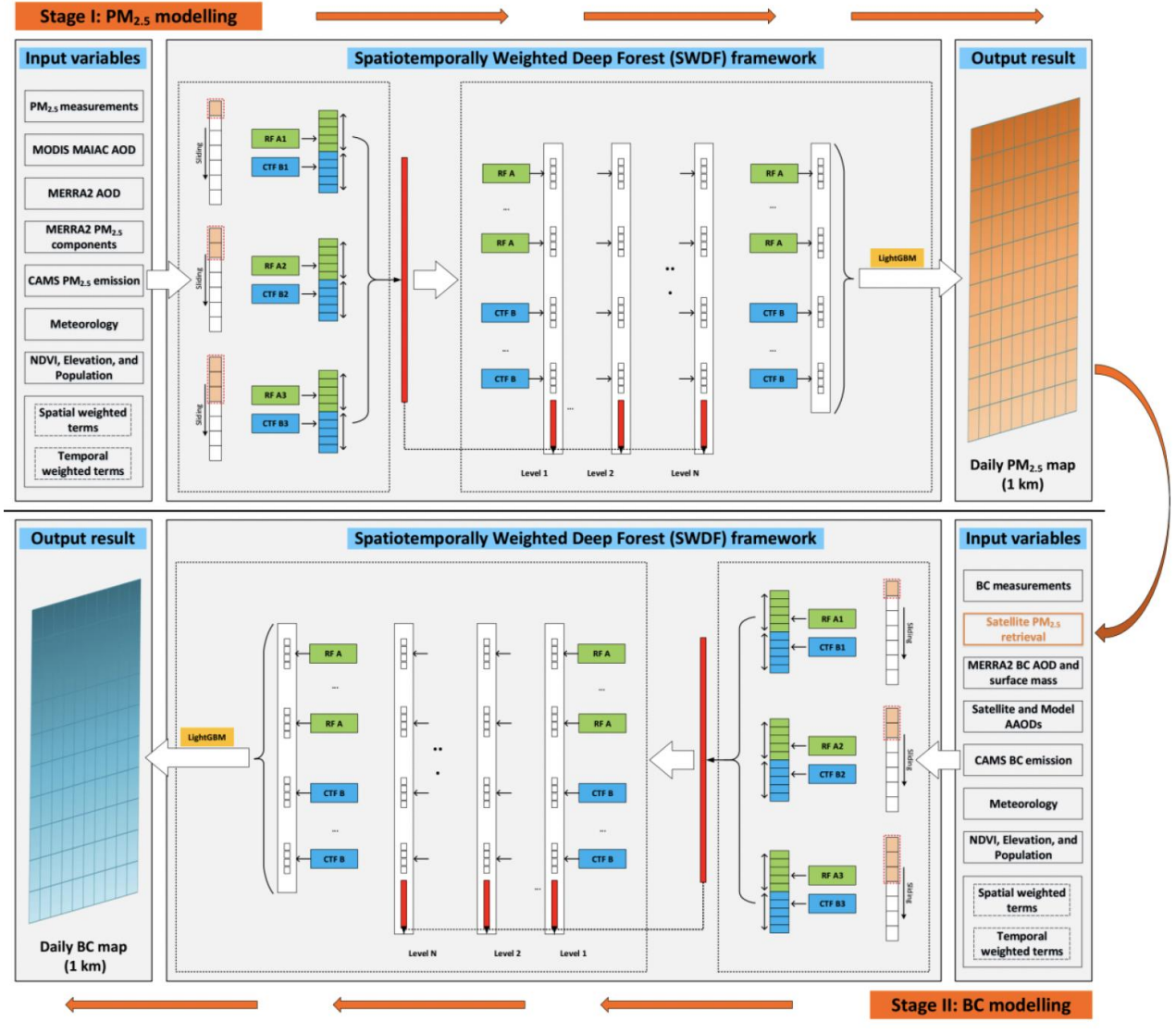
Input Data



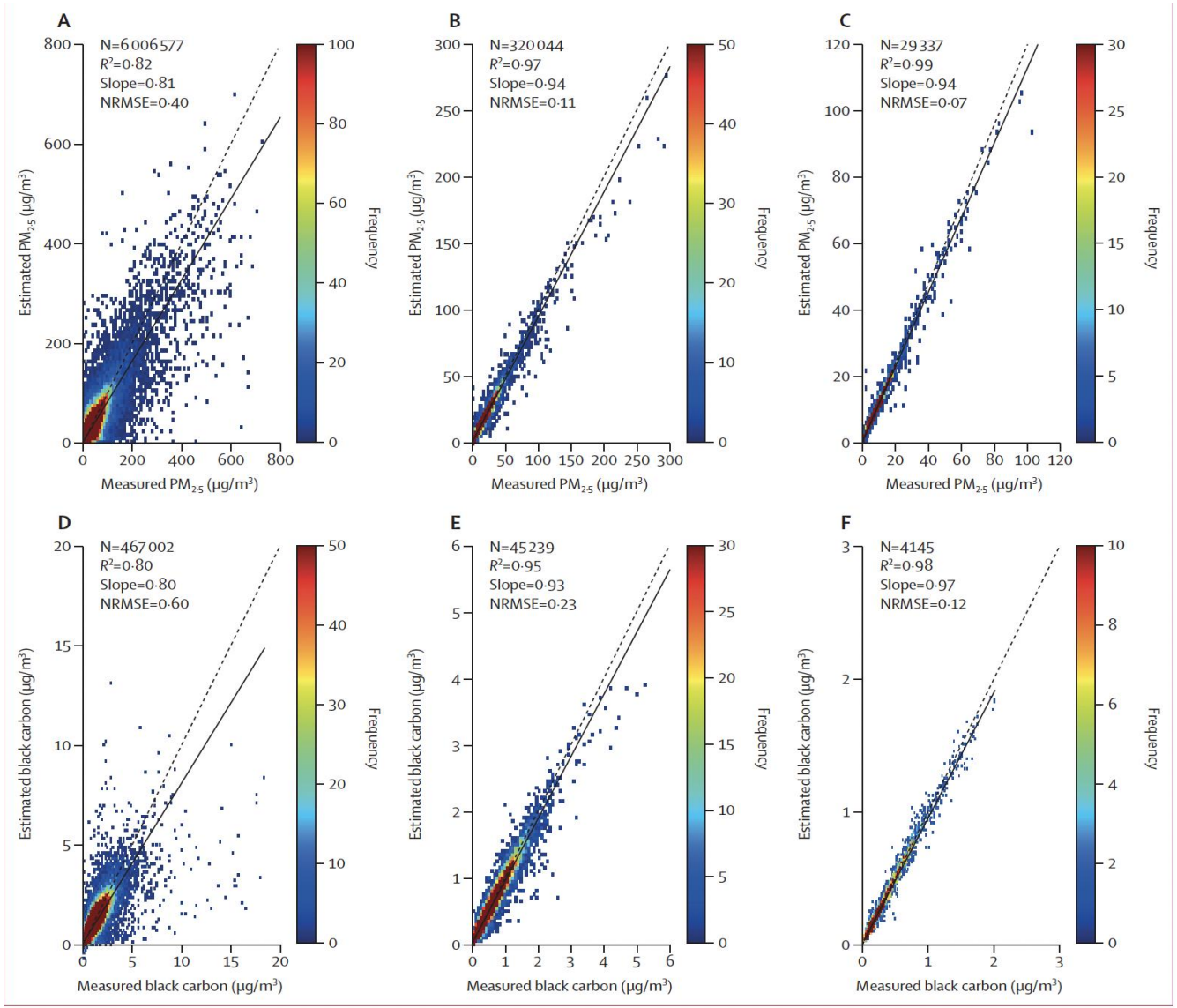
Satellite remote sensing product	MAIAC AOD
	Absorbing AOD
	NDVI
	Elevation
	Population distribution
Chemical model simulation	Total aerosol extinction AOD
	Absorbing AOD
	Black carbon extinction AOD
	BC surface mass concentration
	OC surface mass concentration
	SO_4 surface mass concentration
	Dust surface mass concentration
	Sea salt surface mass concentration
Emission inventory	Black carbon
	Ammonia
	Nitrogen oxides
	Sulphur dioxide
	Volatile organic compounds
	Smoke emissions
Meteorological data	2-m air temperature
	Total precipitation
	10-m u-component
	10-m v-component
	Surface pressure
	Boundary layer height
	Relative humidity



Spatiotemporally weighted deep forest (SWDF)

It uses the cascade structure by including multiple random forests and extremely randomized trees in each middle layer.

The final result was determined by integrating the results of all intermediate hidden layers using the Light Gradient Boosting Machine.



Sample-based cross validation

Concentration–response functions (CRFs)

Relative risk:

$$RR(x) = \begin{cases} 1, & x < x_0 \\ e^{\beta \Delta x}, & x \geq x_0 \end{cases}$$

All-cause mortality burden (MB):

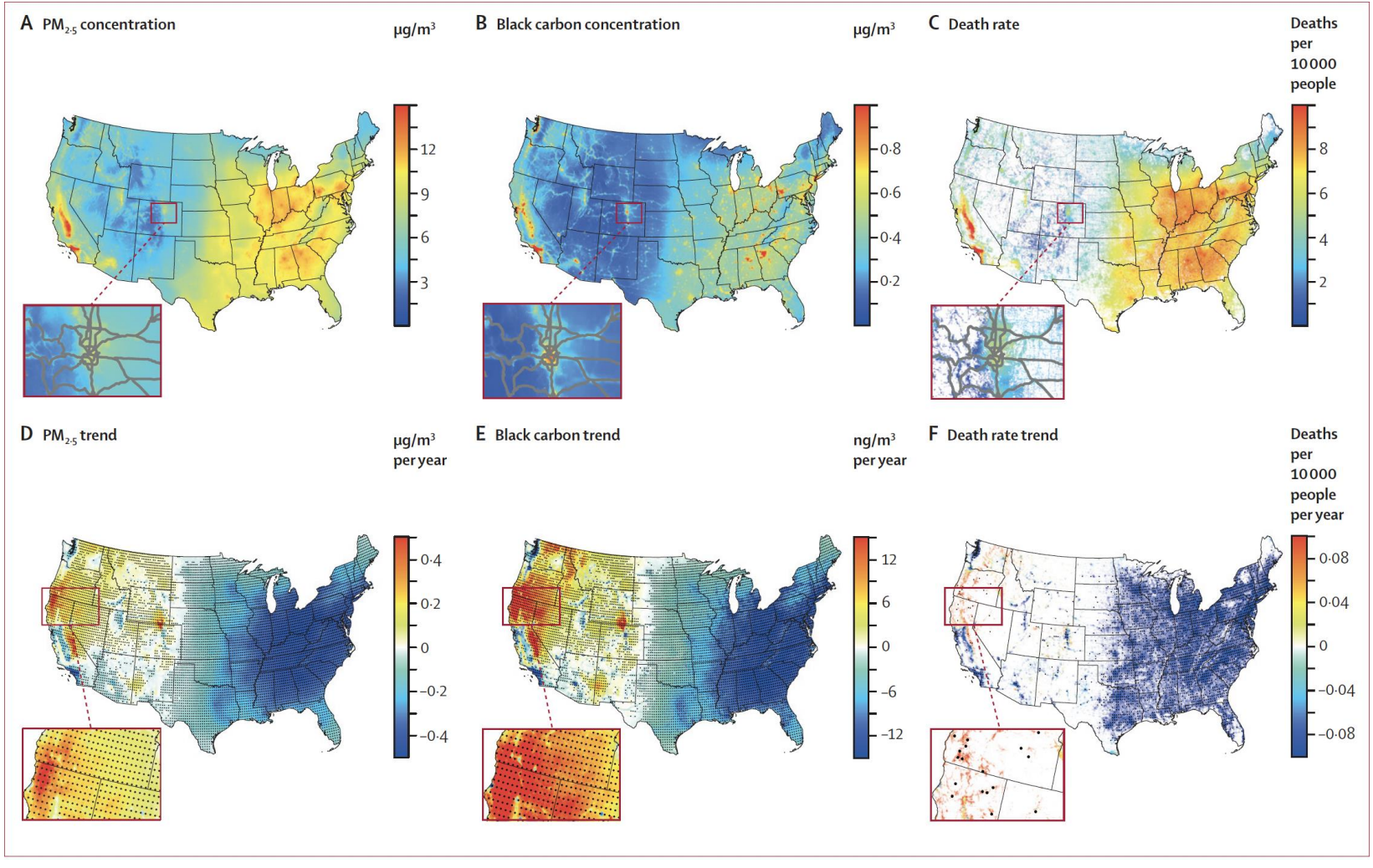
$$MB = \frac{RR-1}{RR} \times BMR \times POP$$

Baseline mortality rate : BMR
Population: POP

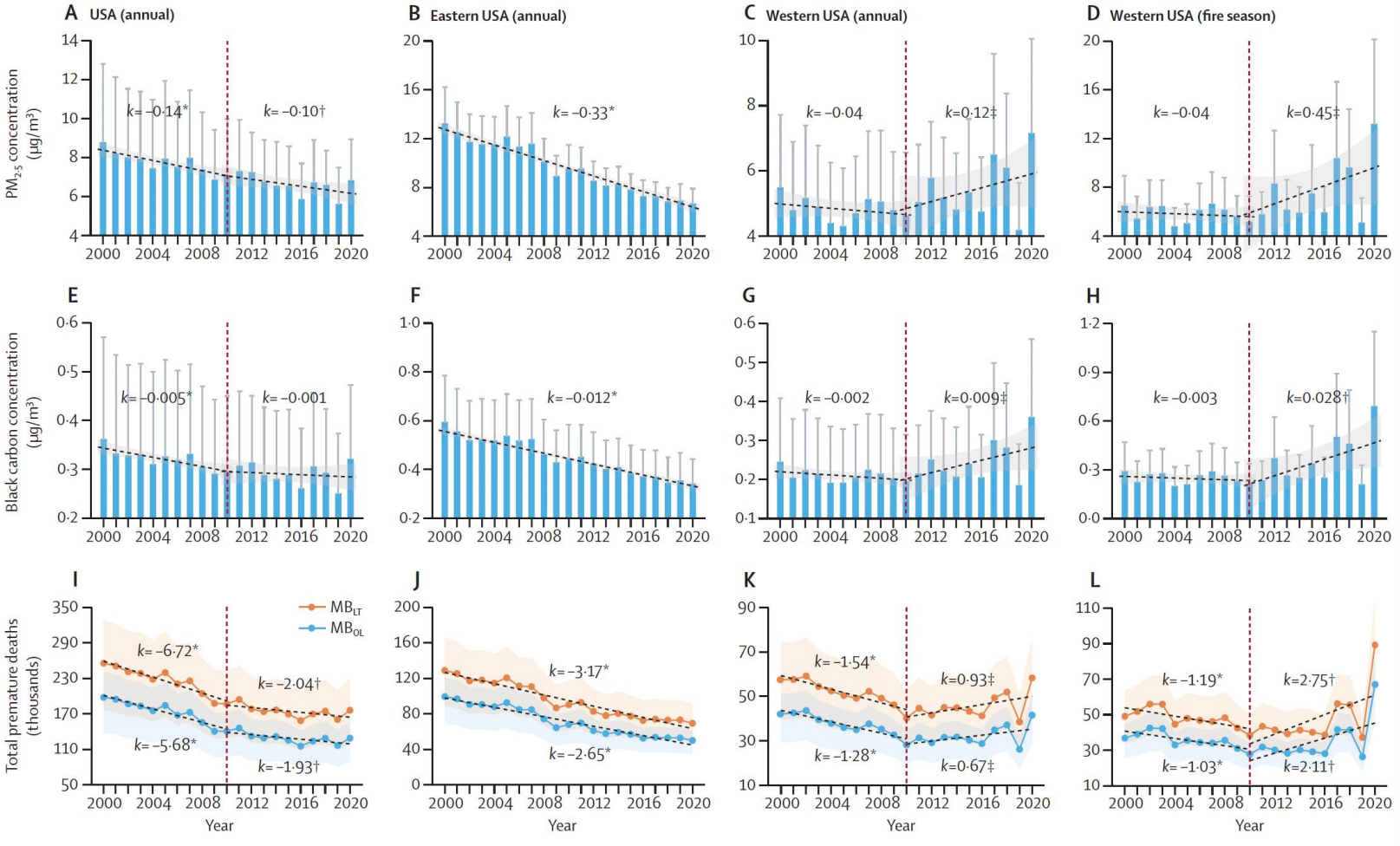
If we consider BC has larger toxicity:

$$MB_{LT} = MB(RR_{PM_{2.5}})_{PM_{2.5}-BC} + MB(RR_{\mathrm{BC}})_{BC}$$

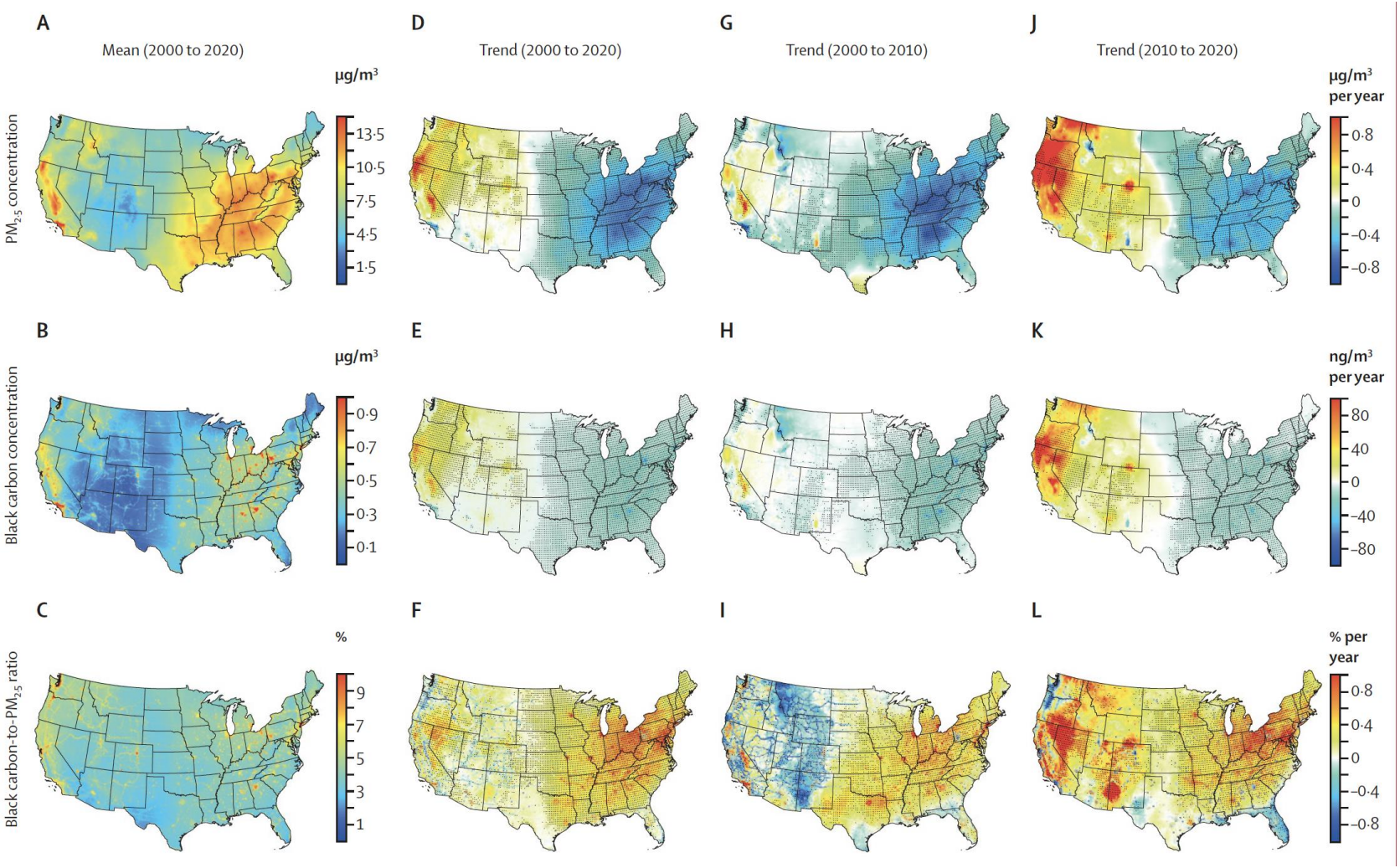
Spatial distribution



Trend by region



Trend by time period



Summary

- Both PM2·5 and black carbon in the USA showed significantly decreasing trends overall during 2000 to 2020 (22% decrease for PM2·5 and 11% decrease for black carbon), leading to a reduction of around 4200 premature deaths per year (95% CI 2960–5050).
- However, since 2010, the decreasing trends of fine particles and premature deaths have reversed to increase in the western USA (55% increase in PM2·5, 86% increase in black carbon, and increase of 670 premature deaths [460–810]), while remaining mostly unchanged in the eastern USA.
- The black carbon-to-PM2·5 mass ratio increased annually by 2·4% across the USA, mainly due to increasing wildfire emissions in the western USA and more rapid reductions of other components in the eastern USA, suggesting a potential increase in the relative toxicity of PM2·5.
- When the greater toxicity of black carbon is considered, PM2·5 led to an increase of around 930 deaths per year in the western USA, compared with an increase of 670 deaths per year when black carbon is not considered. This is much higher than the number of casualties directly caused by wildfires (around 89 deaths per year in the USA). The health benefits from air quality improvement measures are significantly offset by wildfires.

With the change of annual standard…