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The 29th AIM International Workshop

Historical global fire smoke and its impact on human health

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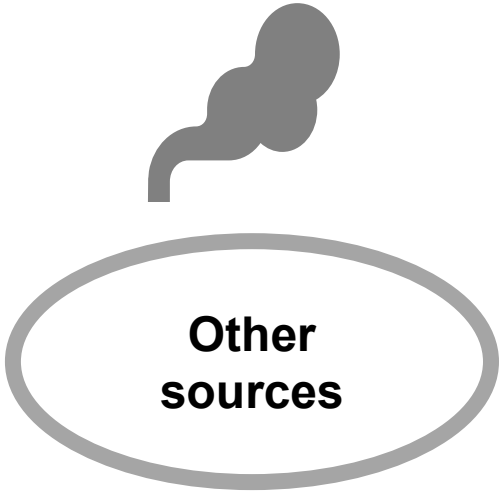
Background

Primary PM2.5 + PM2.5 Precursors

BC, OC

VOC, NOx, SO2, NH3, …

Fire Emissions
(Gases and Aerosol)



Urban (road, industry),
sea, agriculture, …

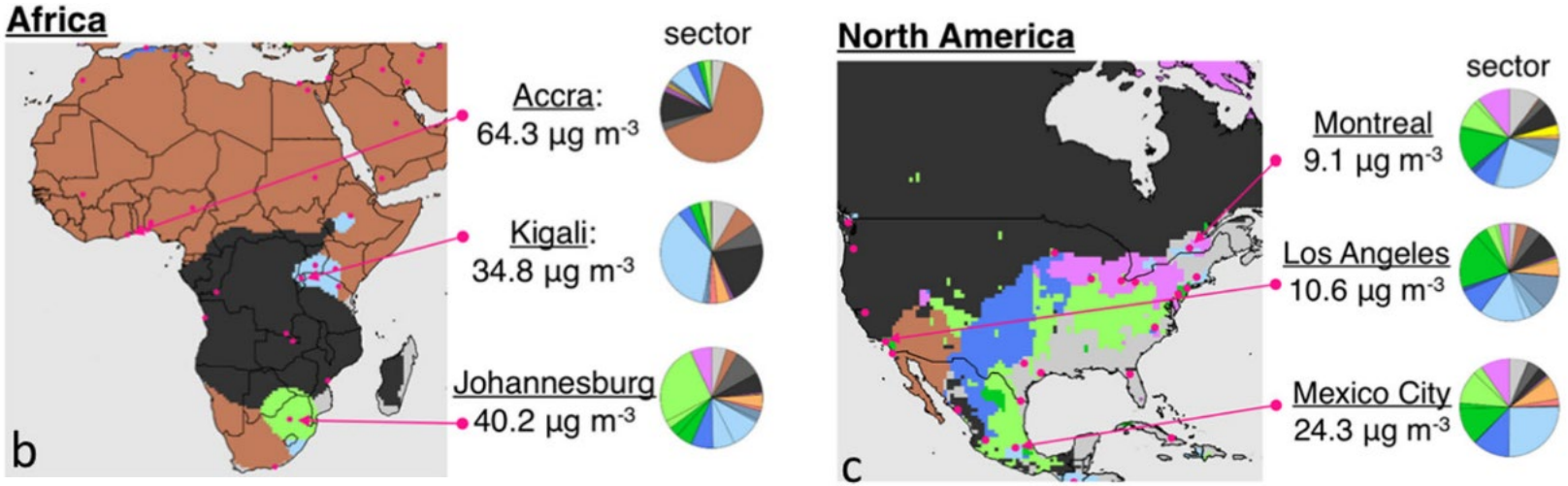
Ambient $PM_{2.5}$ pollution
fine particulate matter with a diameter of ≤2.5 μm ($PM_{2.5}$)

Health burden of stroke, cardiovascular, respiratory diseases and deaths

In 2016, 4.2 million premature deaths

Background

Fire accounted for 4-21% of annual mean $PM_{2.5}$ mortality (2000s ~ 2010s)

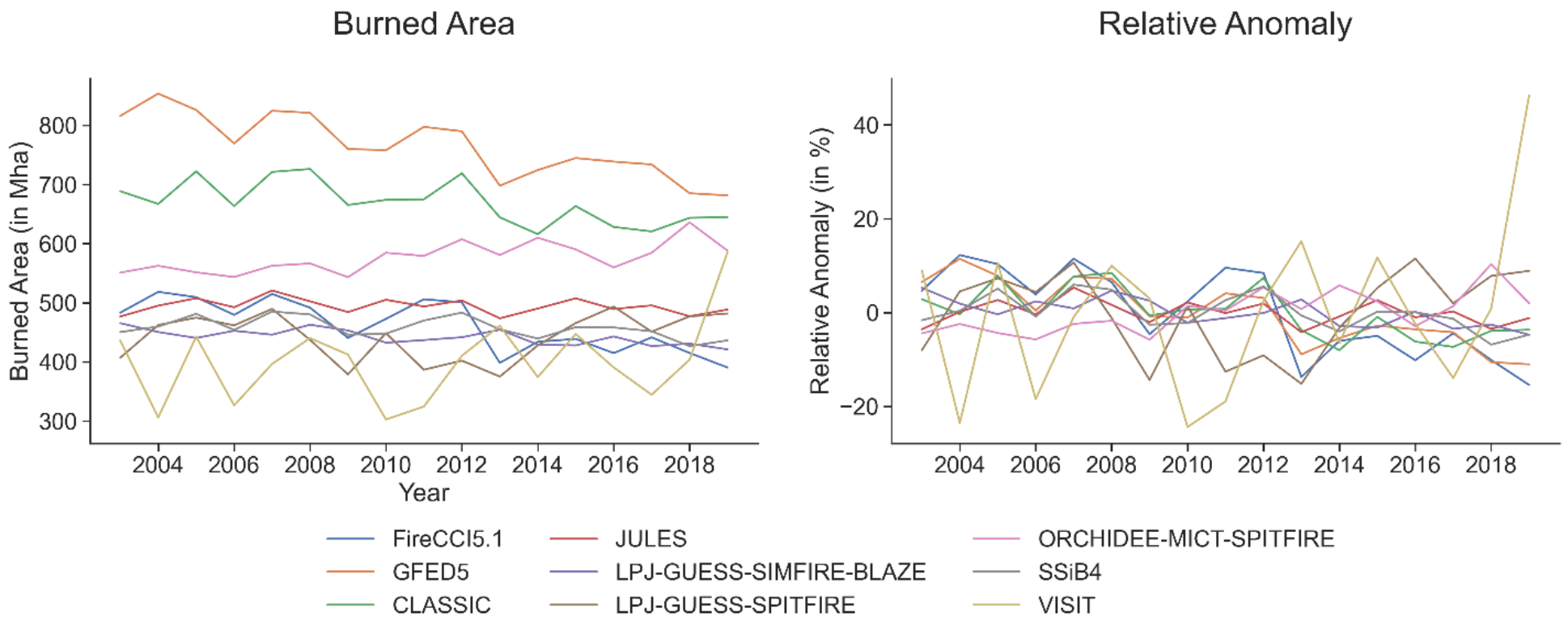


Black : dominant contributor of $PM_{2.5}$ is fire

McDuffie et al., 2021 Nature communication

Background

ISIMIP3 (Inter-Sectoral Impact Model Intercomparison Project) – Fire-vegetation models : historical bunred area simulation from 1901 to 2019

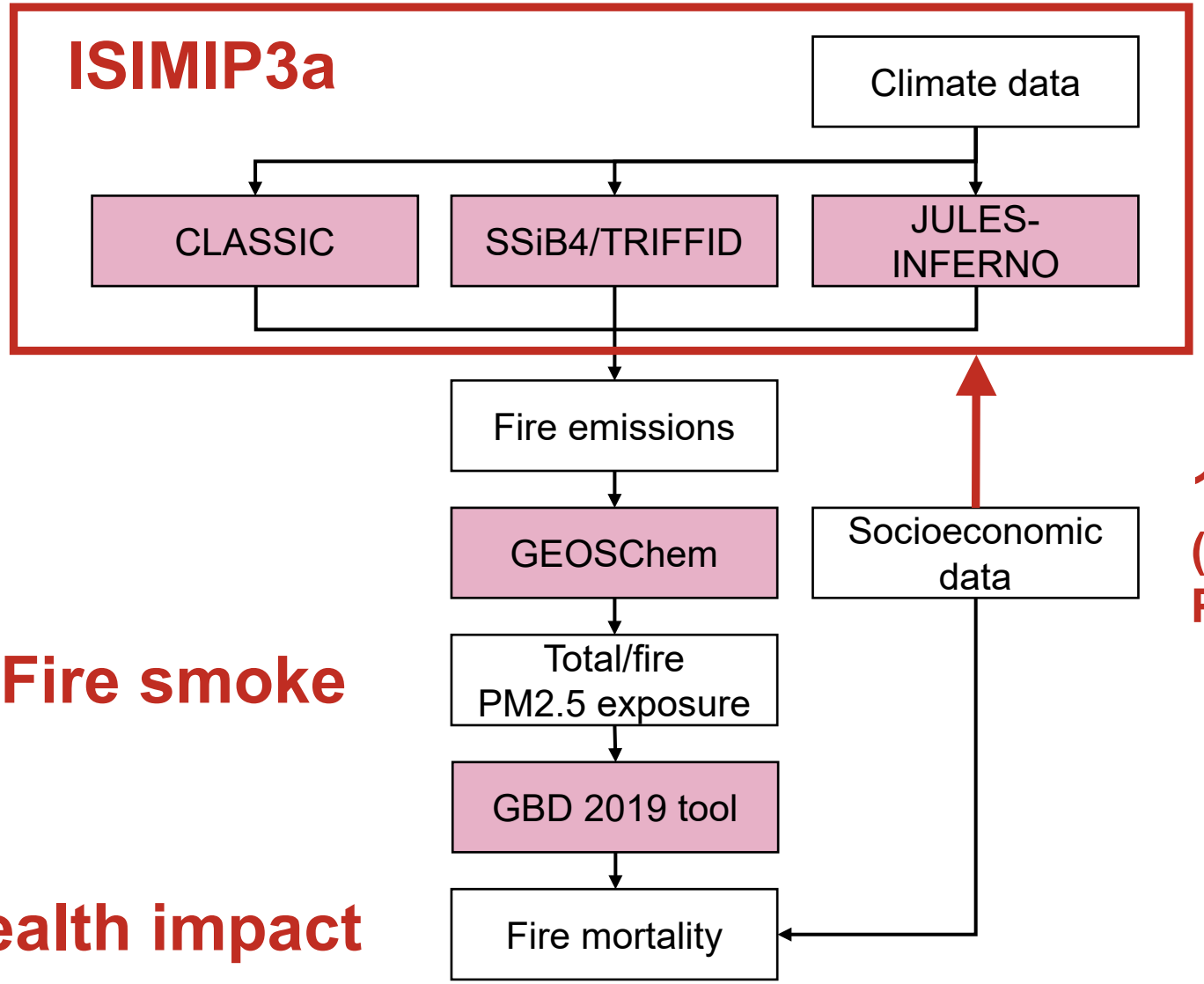


*Burton et al., preprint (**Annual burned area and relative anomaly for observations and models**)*

Research aim

Investigate temporal and spatial patterns of global fire $PM_{2.5}$ and its attributable mortality over the past 60 years by using three fire-vegetation models, provided by the ISIMIP3a

Methods



Fire smoke

health impact

1960s – 2010s
(decadal mean annual $PM_{2.5}$ exposure)

Health impact analysis

$PM_{2.5}$ Mortality from six diseases

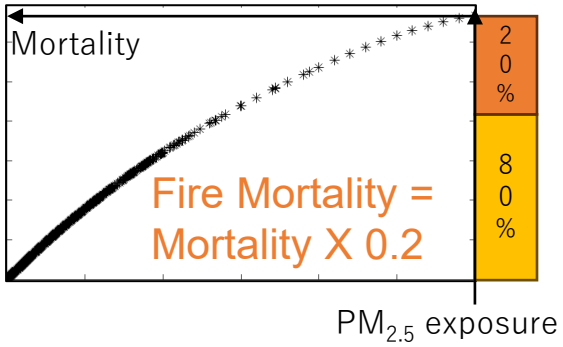
- chronic obstructive pulmonary disease
- lung cancer
- ischemic heart disease
- type II diabetes
- stroke
- lower respiratory infection (< 5yr)

$PM_{2.5}$ Mortality attributed from fire

Total $PM_{2.5}$ mortality × Fire contribution to $PM_{2.5}$

$$\text{contribution} = \frac{PM_{withFire} - PM_{withoutFire}}{PM_{withFire}}$$

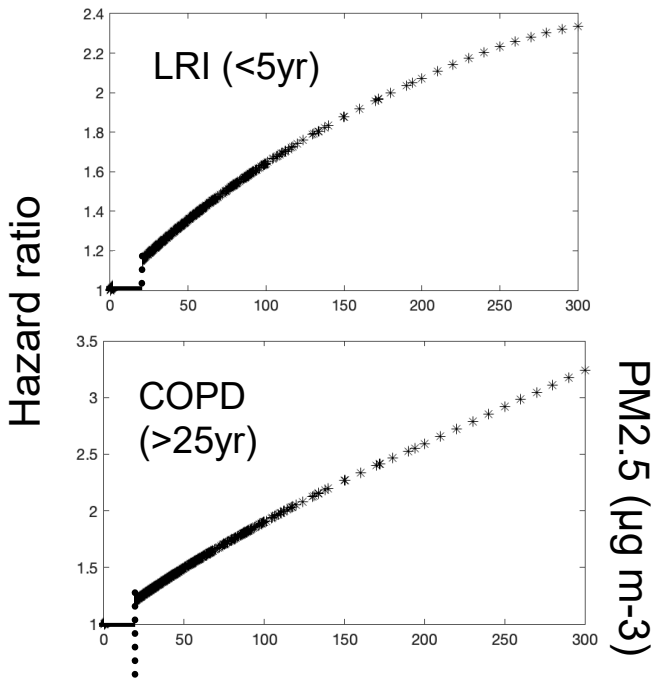
$PM_{2.5}$ exposure – mortality relationship is not linear, and assumed that all PM2.5 source have same toxicity (limitation of the study)



Health impact analysis

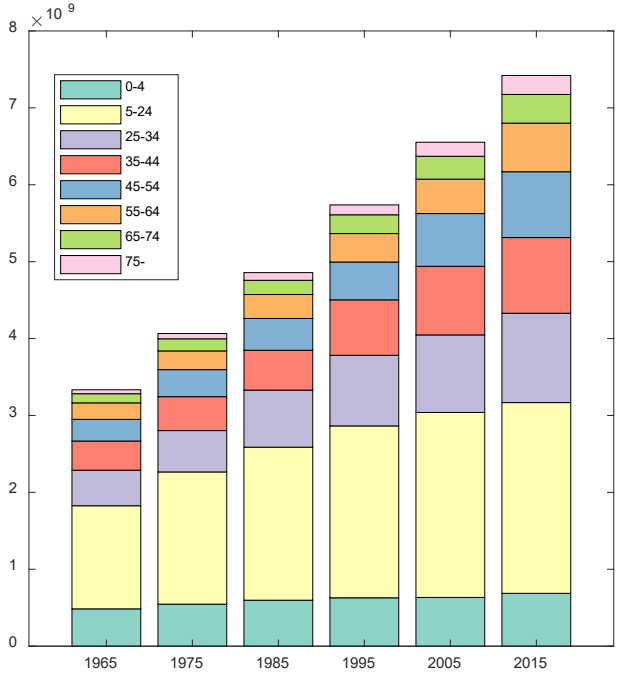
$$Mortality = \frac{Hazard\ Ratio_{d,a,i} - 1}{Hazard\ Ratio_{d,a,i}} \times Population_{a,i} \times BaselineMortality_{d,a,i}$$

Hazard ratio

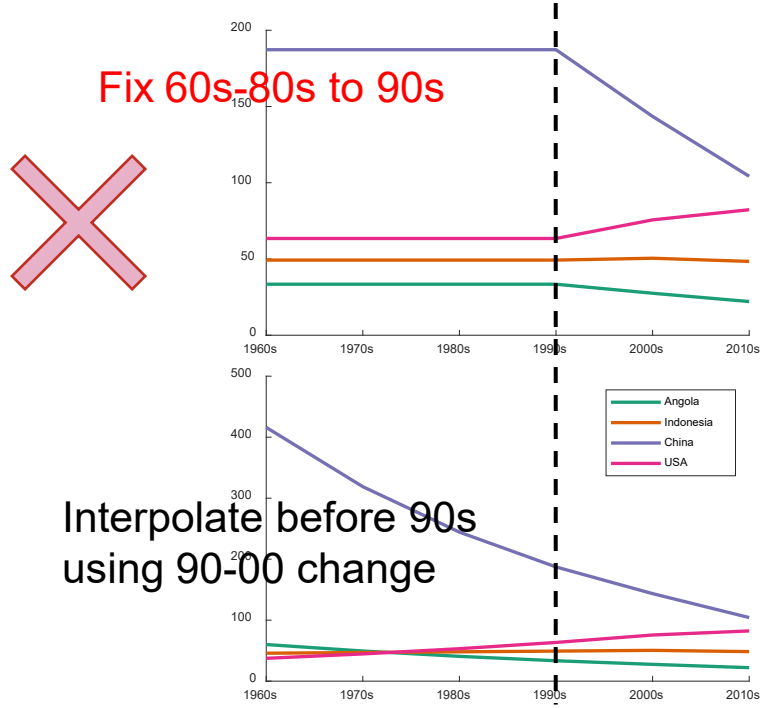


theoretical minimum risk exposure level =2.4

Global population

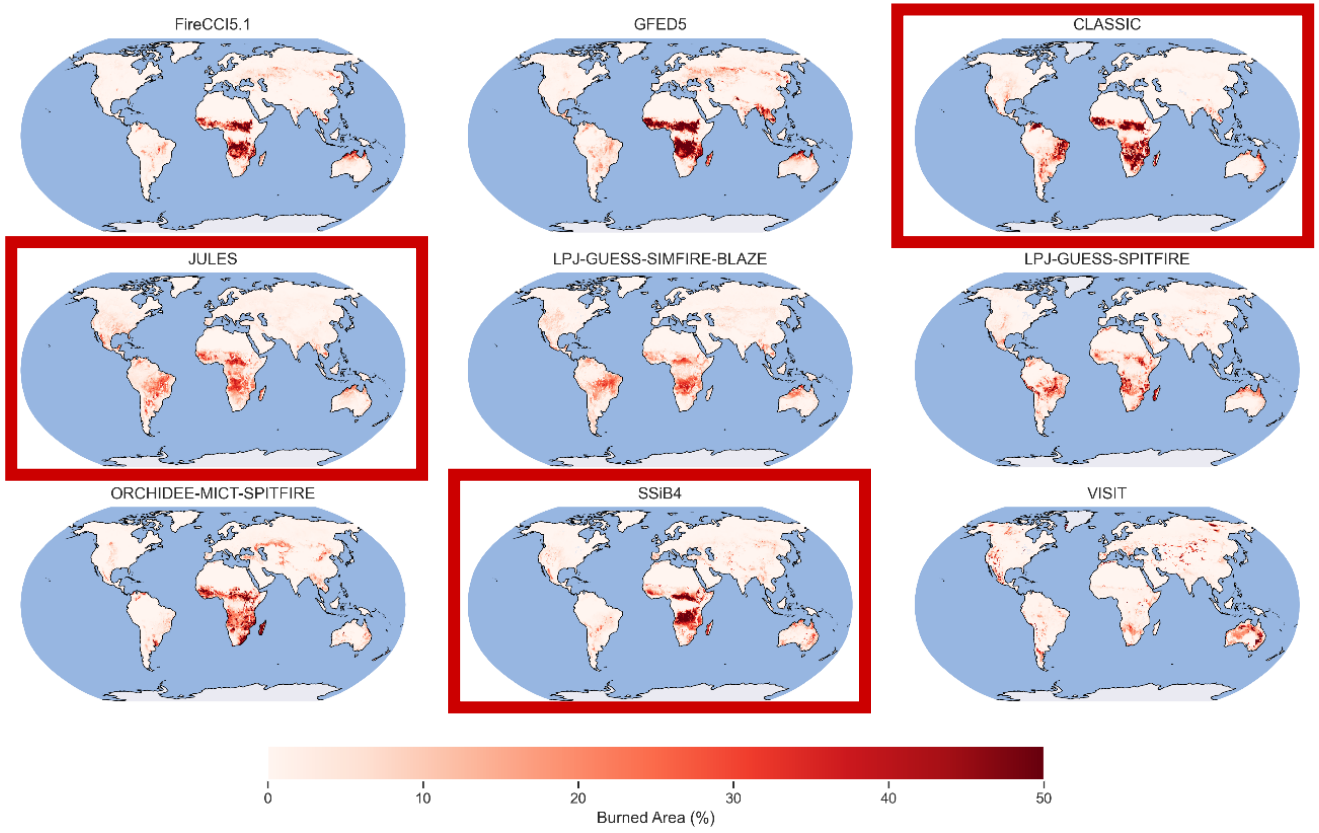


Baseline mortality



Fire-vegetation model (ISIMIP3)

Three **fire-vegetation** models
(burnred area)



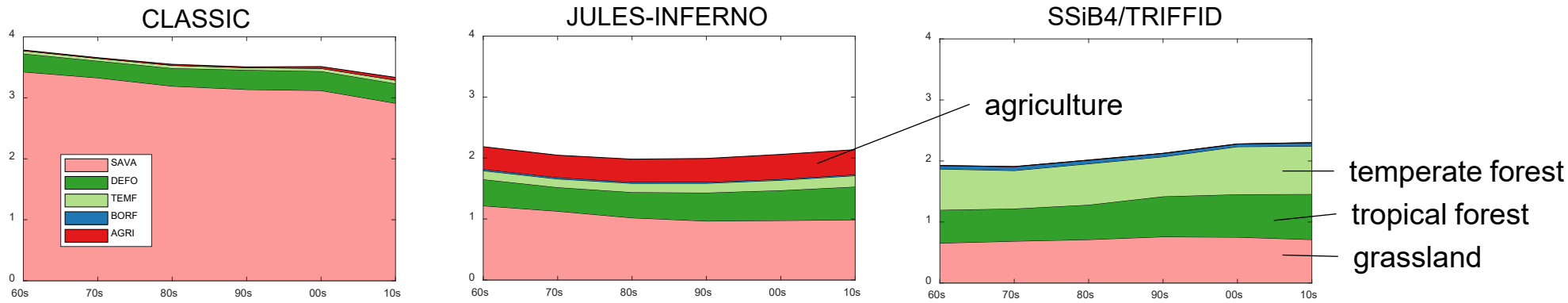
Burton et al., preprint

biomass
soil moisture

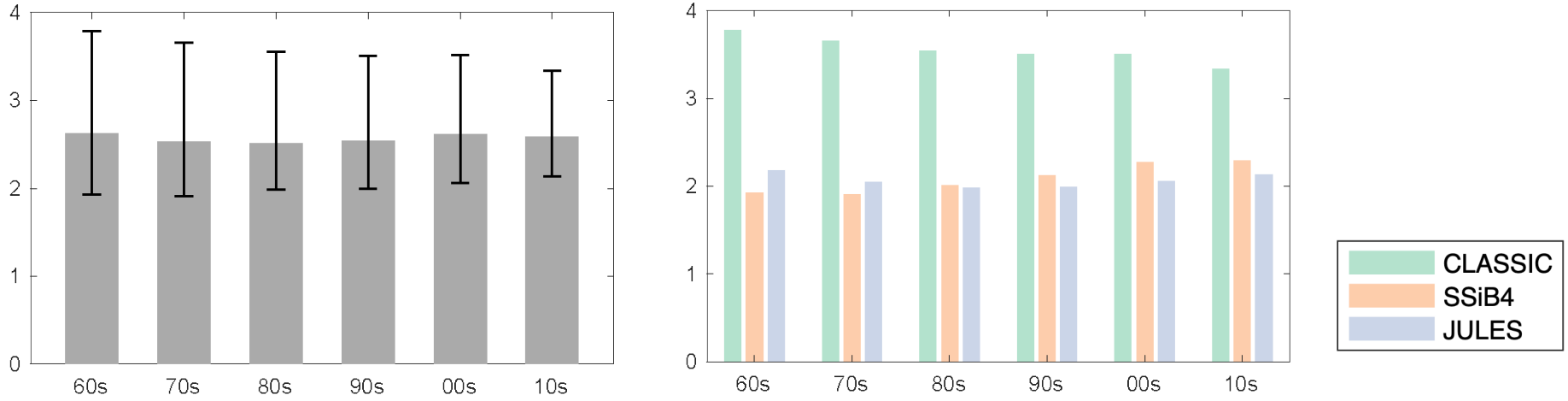
Fire emissions

Fire-vegetation model

Fire carbon Emissions (Peta gC/yr) – by fire type



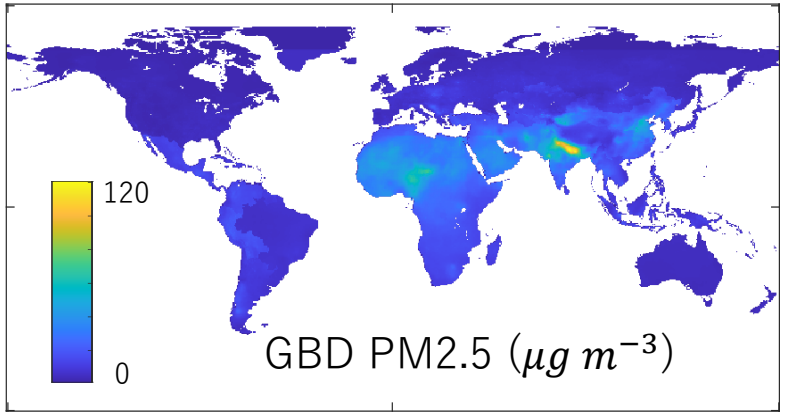
Total carbon emissions (model mean, Peta gC/yr)

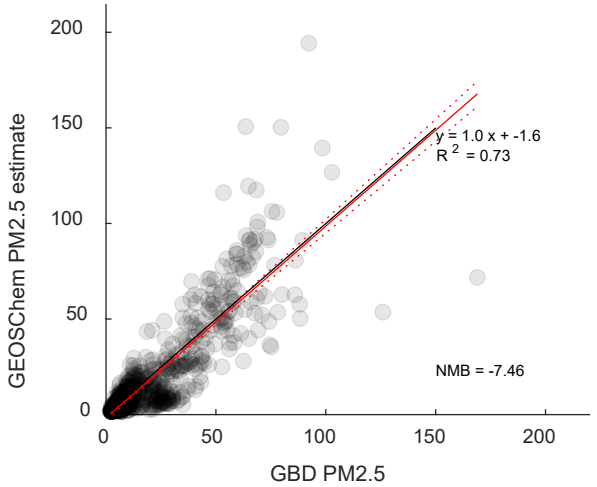


GEOS-Chem (validation results)

Total ambient PM2.5 (With Fire)

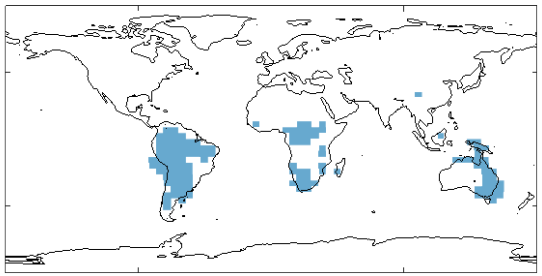
: Validate GOESChem results with satellite-based product (GBD results), R^2=0.73

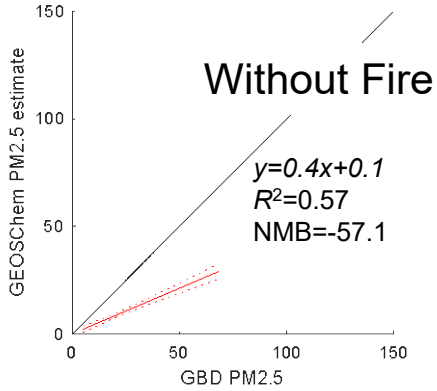




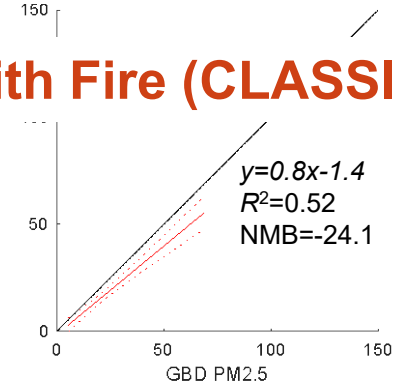
Reasonable validation results for ambient PM2.5 concentration simulation

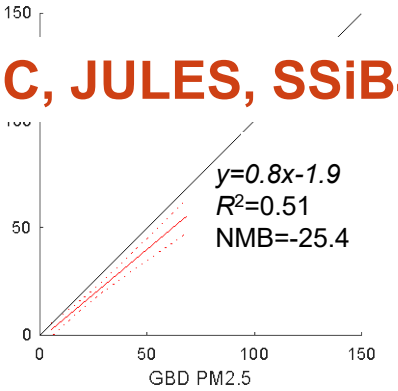
Fire contribution > 30%

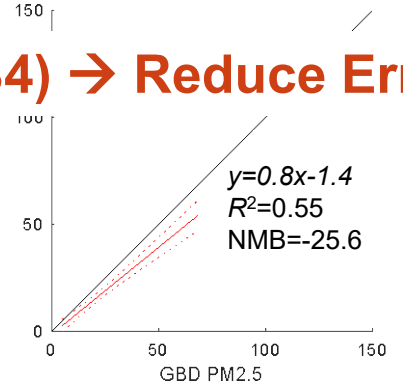




With Fire (CLASSIC, JULES, SSiB4) → Reduce Error

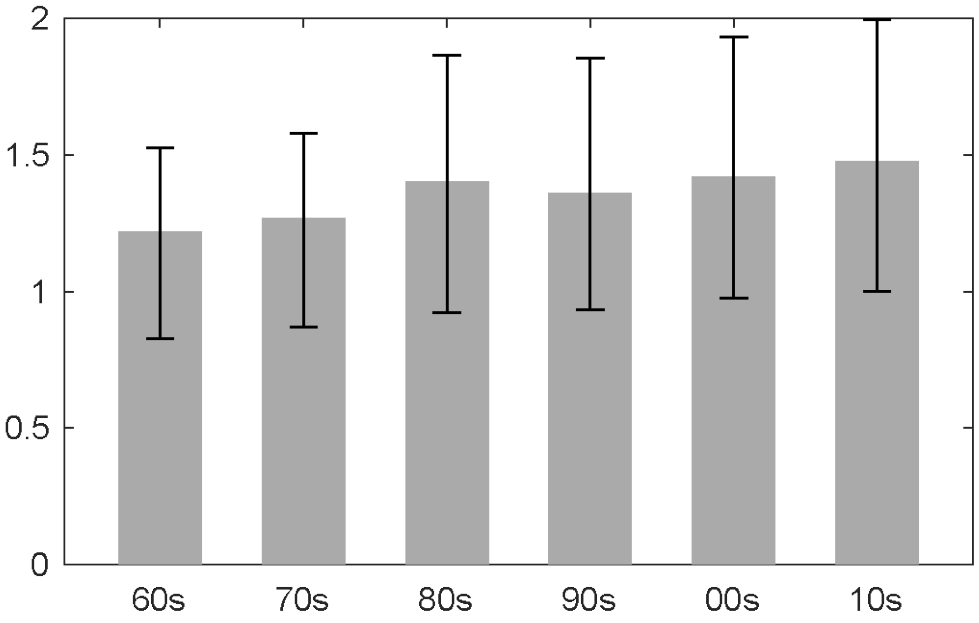




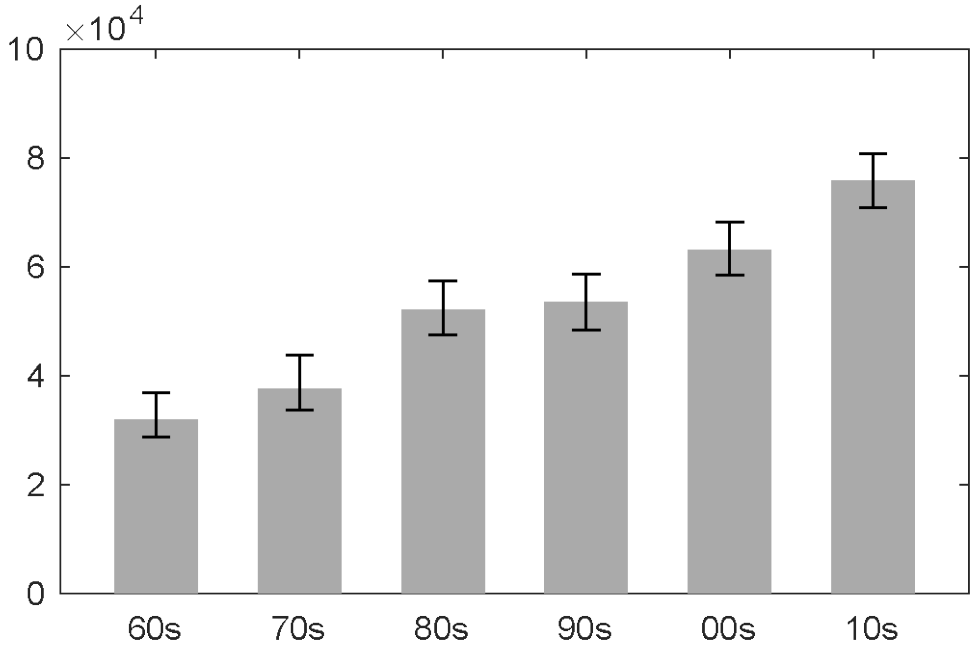


Fire impacts (1) global changes

Fire $PM_{2.5}$ (μg/yr/m3)



Fire Mortality (death/yr)

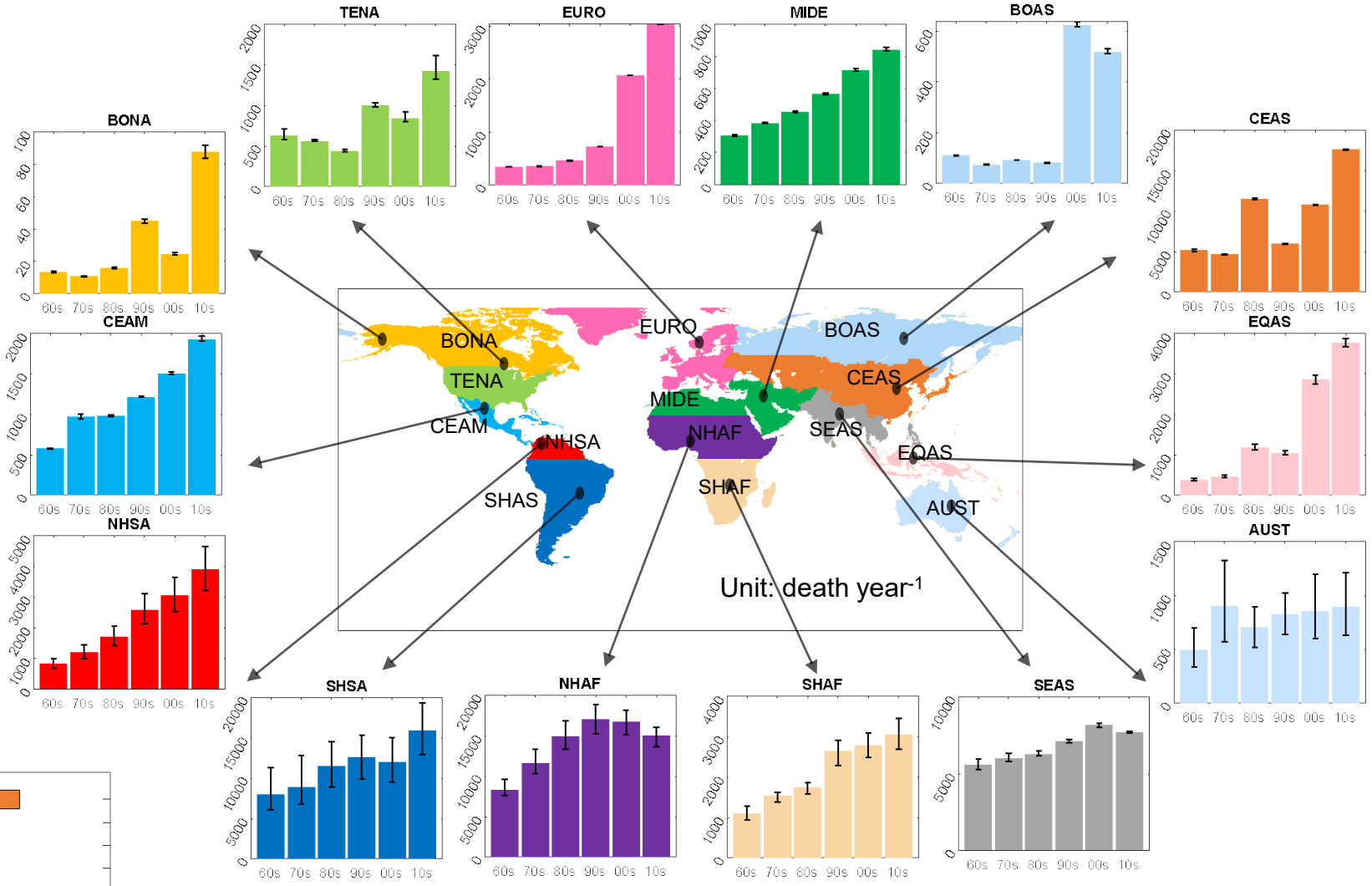


Fire PM2.5 has been increased slightly over last 60 years. Fire mortality has been increased much steeply due to population increase

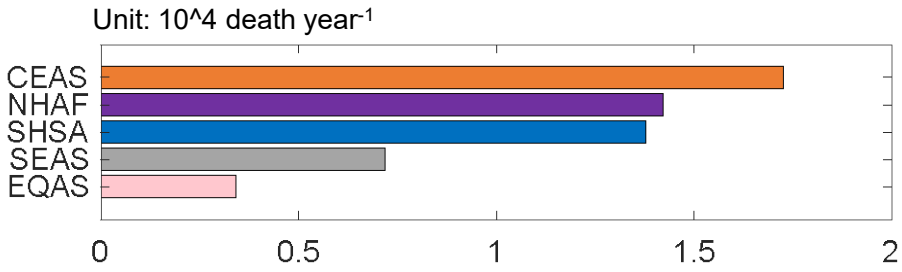
Fire impacts (2) Regional change: annual death

Fire has affected largest mortality in **Central and East Asia (CEAS)** with increasing trend

Northern hemisphere of Afirca (NHAF), Southern hemisphere of South America (SHSA) followed



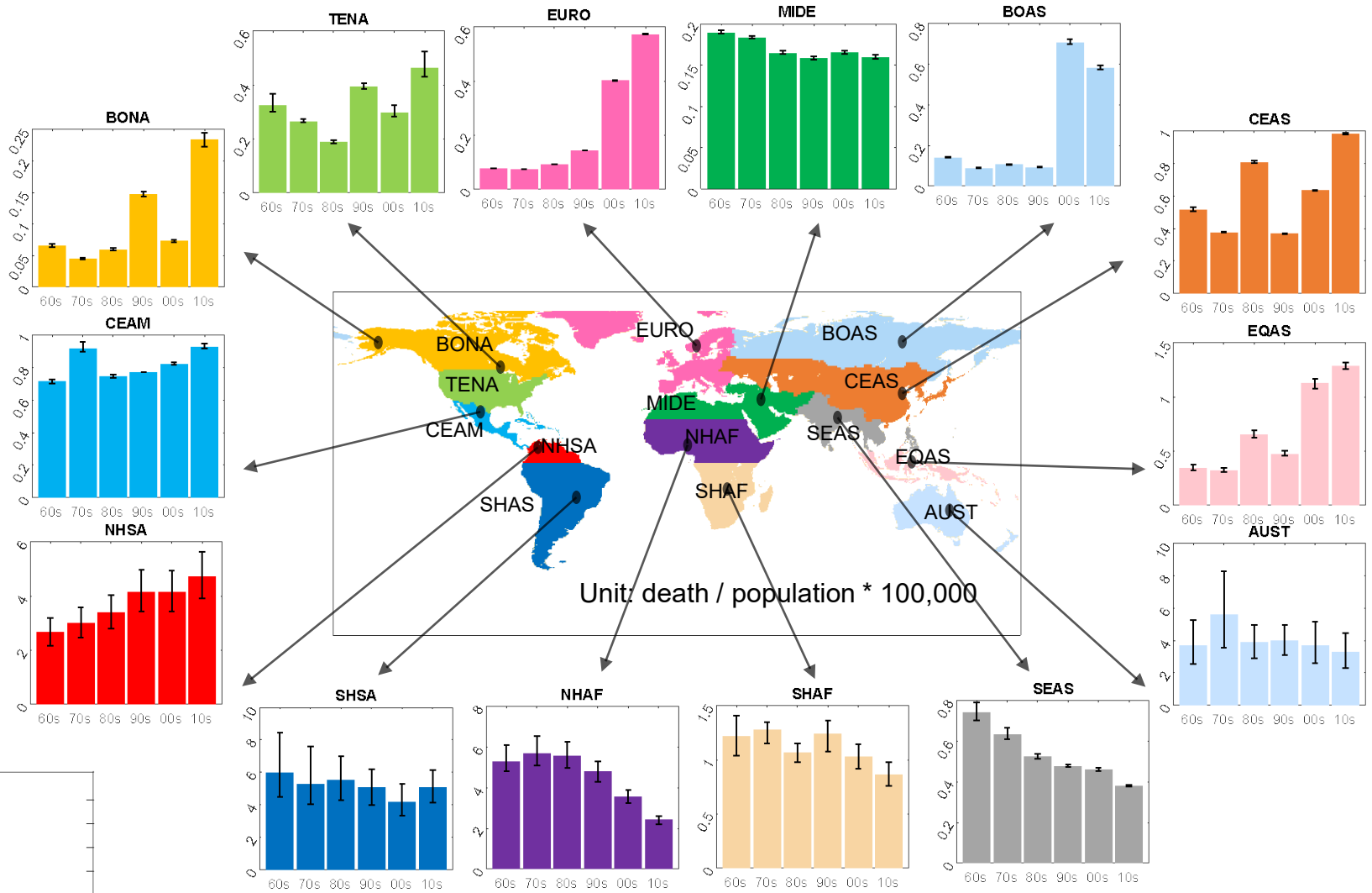
Top-5 regions in 2010s



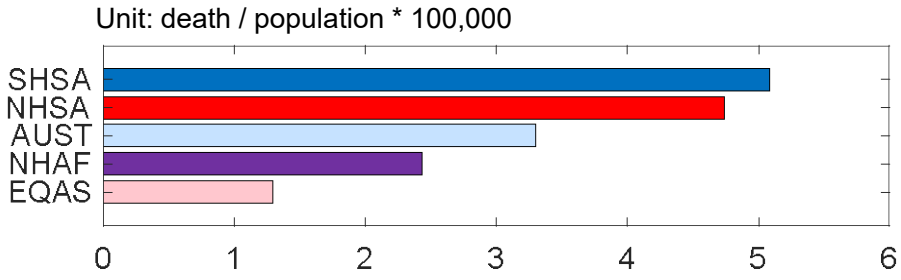
Fire impacts (2) Regional change: annual death ratio (/population)

Fire mortality ratio was increased in Europe, boreal forests (BONA, BOAS), Eqatorial Asia (EQAS), and northern hemisphere of South America (NSHA).

<u>Tropical regions</u> have the highest death rario in 2010s.

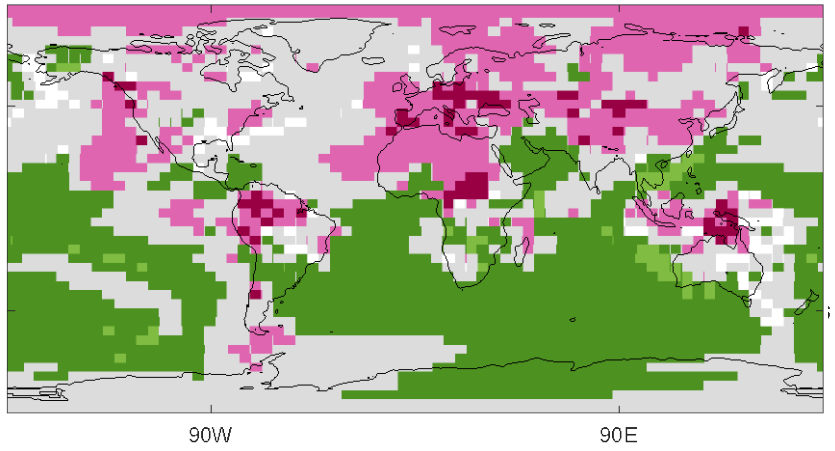


Top-5 regions in 2010s

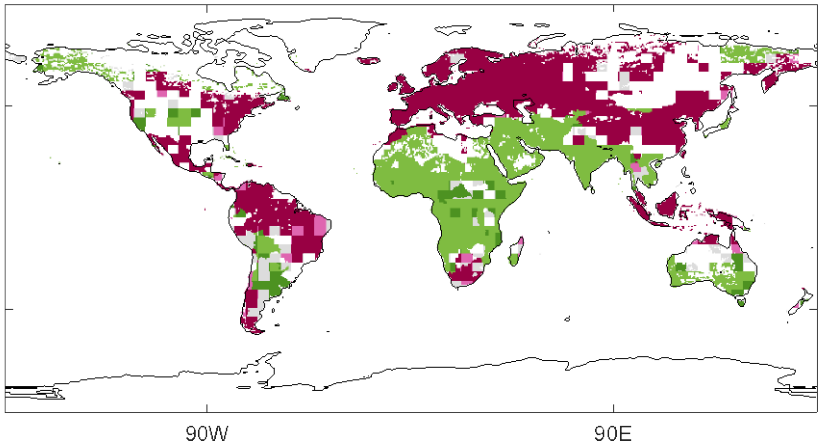


Fire impacts (3) Model agreements in temporal change

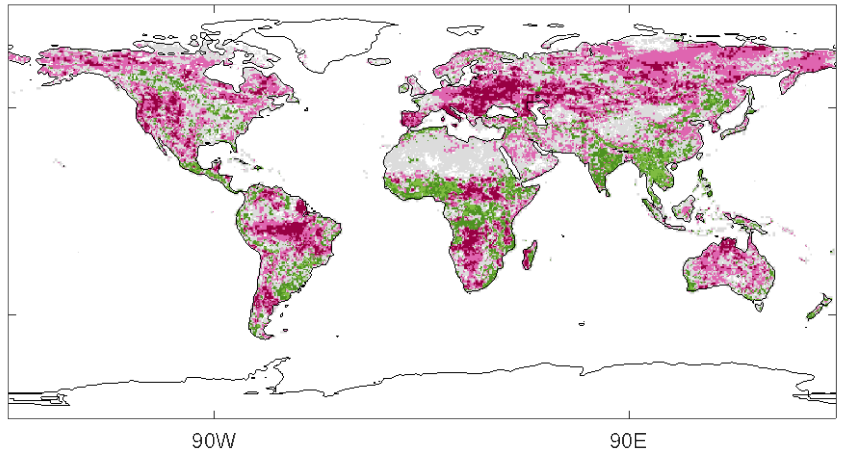
Fire PM2.5



Fire mortality ratio (death/population)



Fire mortality



2-3 models among 3 models showed **agreements in increased fire impact in high latitue area & equitorial Asia**, **Northern part of South America, and northern Australia** for the last 6 decades.

High agreement in decreasing : 3/3

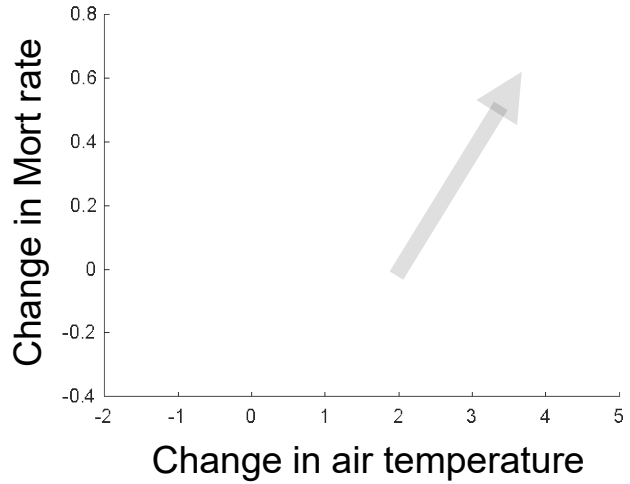
Agreement in decreasing : 2/3

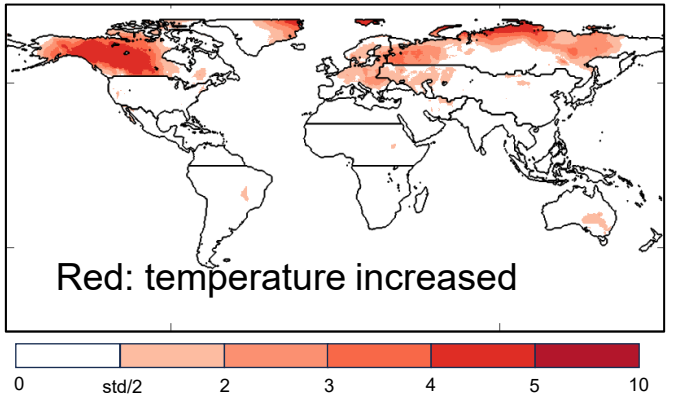
Agreement in increasing: 2/3

High agreement in increasing: 3/3

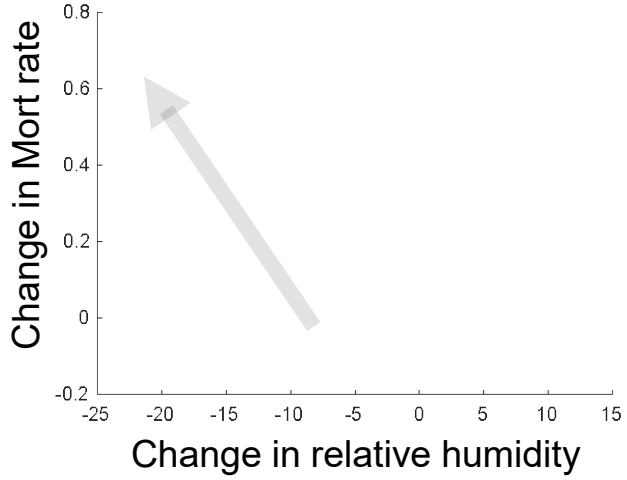
Fire impacts (4) Temporal changes in Mortality rate & climate change

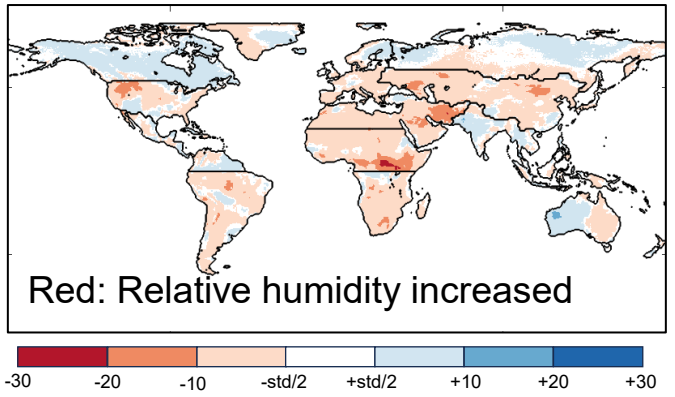
2010s – 1960s





Some regions where **air temperature has increased (~4ºC)** increased mortality rate.





Some regions where **relateive humidity has decreased (-5~25%)** increased mortality rate.

(Based on SSiB4 model)

Taking home message

Limitations

- Lack of baseline mortality data before 1980s : two assumption leads large difference
- Number of fire-vegetation models

Key finding

- Fire $PM_{2.5}$ contributed to 1.3-1.4 μg/m3 among 23.5-37.3 μg/m3 ambient $PM_{2.5}$ exposure
- Fire $PM_{2.5}$ contributed to 37,000-81,000 among 1.2-3.3 million $PM_{2.5}$ mortality
- The fire $PM_{2.5}$ impacts varied across region
  : total death was highest in the Central and East Asia
  : death ratio was highest in the tropical regions
- Temperate forests and Amazon forests showed an increasing trend with high model agreement
- The changes in historical fire impacts may have a relationship between climate change

Thank you for listening !

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